THE ILEO-CÆCAL VALVE

RUTHERFORD

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Walter C. Alvarez

Microscopical vertical section of Specimen No II.
(Stained H. and E.)

Frontispiece]

THE ILEO-CÆCAL VALVE

BY

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PREFACE

THE contents of this book constituted a thesis for the M.D. degree submitted to the University of Edinburgh. A short paper was read on the subject before the Physiological Section of the International Medical Congress, London, 1913.

The term "ileo-cæcal valve" in this book is used in the sense that the pylorus is spoken of as the pyloric valve—that is to say, as a term applied to the orifice between the small and large intestines, and the anatomical structures immediately adjacent and intimately concerned with this orifice. It is not used to denote the function of the ileo-cæcal valve.

I wish to express my gratitude to Professor J. T. Wilson, of the Sydney University, for his hospitality in placing his rooms and library at the Anatomical School at my disposal.

Also I wish to thank Dr. A. A. Palmer, Assistant Medical Officer, Sydney, for helping me obtain the fresh specimens.

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PART I

LITERATURE DEALING WITH VALVULA COLI

In considering the literature dealing with the valvula coli we find descriptions of two distinct types. The first and older descriptions are those dealing with specimens which have been inflated first and then dried. These descriptions will be placed under the heading of "A." The second type of descriptions is more modern, and deals with those in which fresh specimens have been hardened, usually *in situ*. The method of hardening is not always the same, but the result is similar—the preservation of the shape and characteristics of the fresh specimens at the time of hardening. Toldt[1] uses a concentrated watery solution of picric acid, followed by alcohol (80 to 85 per cent.), or, if merely to preserve the form, 1 per cent. commercial formalin. Others use intravenous injections of formalin (Birmingham[2]) or merely harden in formalin (Symington[3]). In most modern textbooks both types of descriptions are given, one following the other. The relative value of these two methods is under dispute. Toldt[1] remarks: "In regard to the treatment of the material, it appears not unimportant at the beginning to remark that distended and dried cæca, which are usually used in anatomy schools, give only an incomplete and no way reliable view of the relations of form. In order to dry a cæcum well, one has

to distend it as much as possible. By this process various changes of form take place, which partly also are dependent on the previous treatment. At best, one obtains merely the form of the specimen distended to its uttermost."

Struthers[4] and Parsons[5] are advocates of the inflated and dried forms.

In referring to Toldt's[1] methods, Parsons[5] remarks, speaking of inflation by gas: "I am sure that the alteration brought about by drying the cæcum is very trivial."

Many observers, though they do not condemn the dried inflated specimens, accept the results with reservation or show specimens hardened in formalin. Figs. 139 and 140 of Symington[3] are from specimens hardened in formalin. Werner Spalteholtz[6] shows diagrams prepared from formalin specimens.

Piersol[7] states *re* injecting water or air from the colon: "These experiments, however, do not represent the true condition during life, since the tonicity of the muscular fibres of the gut is lost."

Birmingham[2] *re* dried inflated specimens, says: "But here again there is danger of falling into error through examining the parts under such artificial conditions."

The appearances described under the two types differ widely from each other, so that it will be advisable to describe them separately.

A. DRIED INFLATED FORM.

In the appearance of the valvula coli in dried specimens Struthers[4] describes the essentials of the normal valve in man as consisting of two crescentic folds, with frenula preventing the flaps being driven through into the ileum. The valve is then complete. Birmingham,[2] Cunningham,[8] Poirier and Charpy,[9] etc., describe the same appearance with slight modification.

Direction of the Opening.

The direction of the opening being from the left and posterior forwards and outwards, it runs horizontally.

Form of the Opening.

In appearance the form of the opening varies slightly from fusiform (Merkel[10]) to rounded at the inner end and pointed at the outer (Poirier and Charpy,[9] and Birmingham[2]).

Dimensions of the Opening.

The length of the opening varies greatly in the dried specimens.

Struthers[4] states (p. 301): "A fair average may be given as: length, $1\frac{1}{4}$ to $1\frac{1}{2}$ inches; breadth, $\frac{1}{2}$ inch—that is, in healthy adult specimens." Merkel[10]: average, 60 millimetres.

Piersol[7] states that: "The average length of the ileocæcal opening on thirty similar specimens was 31 millimetres, the extremes being 46 millimetres and 21 millimetres. It is probable that, owing to the shrinking of the tissues, these dimensions of the opening are excessive."

Relative Size of Segments.

Two segments are described in the dried form. The descriptions dealing with the relative size of the segments are far from uniform.

Piersol[7] states that the lower fold is the larger.

Struthers:[4] Average—lower, 1 inch; upper, $\frac{1}{2}$ inch.

Birmingham[2] also states that the lower is the larger, and that "the size of the segments, as seen in the dried condition, varies considerably."

Poirier and Charpy[9] say of the inferior segment of the valvula coli: "It is higher, but not as long as the preceding one."

Shape of the Segments.

In shape, in the dried specimens, Struthers[4] speaks of "two crescentic folds with frenula."

Birmingham[2] also speaks of "two crescentic segments." Later he says: "They (the segments) are sometimes very imperfect, and even the absence of both has been recorded."

Poirier and Charpy[9] state of the dried specimens: "The orifice is horizontal, and the opening is bounded by two unequal folds with free thin and sharp edges. The superior valve (ileo-colic) resembles the falciform folds, which we have described in the colon, horizontal and half-moon shaped. The inferior valve is very oblique, nearly vertical."

Merkel[10] states: "In the adult the breadth and direction of the lower lip of the valve is determined by the direction of the termination of the ileum. The upper lip is more regularly formed; it is a half-moon-shaped fold projecting into the large intestine, a plica semilunaris."

Cunningham[8] and Gray[14] also describe the dried and distended forms.

Direction of Segments.

Birmingham says: "An upper, in a more or less horizontal plane, forming the superior margin of the aperture; and a lower, which is also the larger, placed in an oblique plane and sloping upwards and inwards."

Poirier and Charpy[9] describe: "The upper lip horizontal, the lower almost vertical."

Frenula.

Frenula, or frenula retinacula, are commonly regarded and described as essential features of the normal ileo-cæcal valve. They are described in both dried and

fresh specimens, between which no essential differences are noted, so that their descriptions need not be separated.

Struthers[4] describes frenula serving to prevent the flaps being driven into the ileum.

Birmingham[2] states: "At each end of the orifice the two segments of the valve meet, unite, and are then prolonged round the wall of the cavity as two prominent folds—the frenula (frenula valvulæ coli). It is thought that when the cæcum is distended, and its circumference thereby increased, these frenula are put on the stretch, and pulling upon the two segments of the valve, they bring them into opposition and effect a closure of the orifice."

Toldt[1] describes the frenula: "The frenula Morgagni are short, and appear only slightly upon the inner intestinal surface." Toldt[1] (p. 63) also describes a most interesting specimen which we may take as resembling the distended and dried specimens in some particulars, and the fresh, hardened specimens in others: "If one has before one, however, the cæcum of a new-born child, or one only a few months old in the distended condition, then the flattened-out, more or less wedge-shaped valve provided with blunt-edged lips projects on the dorsal wall into the lumen of the cæcum (his Fig. 21). The lower lip is considerably shorter than the upper one, its free edge more or less concavely cut out, so that the two valve edges, even in very moderate extension, cannot come into contact. The valve, therefore, is not capable of closing. The flat, elliptical opening of the valve is, according to this, considerably overlapped by the upper lip, and is directed downwards and forwards. Of the two frenula, the dorsal one is especially pronounced."

Poirier and Charpy[9] (*loc. cit.*) describe frenula (p. 327), "which spread, the one anterior, the other posterior, on more than half the internal circumference of the colon, especially in the posterior direction.

Symington,[3] Cunningham,[8] and all other authors describe frenula, their function being described as checks to the valvula coli.

B. FRESH, HARDENED SPECIMENS.

If, now, we consider the descriptions of the valvula coli in the fresh, hardened specimens, we shall find striking differences in regard to the various features specified under the head of the Dried Preparations, with the exception of the frenula, which I have treated as common to the two types. We shall also find that there is no complete agreement among anatomical authorities as to the characteristics of the normal valve.

Speaking of the valve hardened in picric acid and alcohol or formalin, Toldt[1] (p. 63) says: "When in the still-born fœtus at full term the cæcum and ascending colon are empty and contracted, the valve, when exposed, appears as a conical or papilla-like projection of 7 to 8 millimetres in length, which completely fills the lumen of the cæcum. The upper lip of the valve touches, with the whole breadth of its upper surface, the lateral wall of the cæcum. The lower, considerably shorter lip lies against the median wall of the cæcum, and on the other side against the upper lip. The free, rounded end of the completely closed valve is turned towards the fundus of the cæcum. The frenula of Morgagni are short, and project only slightly upon the inner intestinal surface."

Symington[3] (Figs. 139 and 140) describes the valve in specimens hardened *in situ* as follows: "The lower end of the ileum passes upwards and to the right, being at first internal to and then behind the cæcum, and terminates by opening into the large intestine at the junction of the cæcum and ascending colon. . . . When the colon is opened, it appears as a transverse or slightly oblique slit,

about $\frac{1}{2}$ inch in length. This opening is guarded by a valve, composed of two segments, or folds, which project into the large intestine. This is the ileo-colic or ileo-cæcal valve. . . . The upper of the two segments is horizontal, and the lower and larger oblique. At each end of the aperture these folds coalesce, and are then prolonged on each side for some distance round the cavity of the intestine, forming the frenula, or retinacula, of the valve."

Cunningham[8] (p. 457), dealing with formalin specimens, says: "In subjects in which the viscera have been hardened *in situ* by formalin, the ileum presents the appearance of being telescoped into the cæcum, in such a manner as to produce the upper and lower folds which bound the slit-like ileo-cæcal opening, and form the valve flaps."

Merkel[10] states (pp. 582, 583), in speaking of the ileo-cæcal orifice: "In the adult the breadth and direction of the lower lip are determined by the direction of the termination of the ileum; if this ascends more steeply and approaches the large intestine very obliquely, then the lower lip is higher and broader than when the end of the small intestine reaches the large intestine at a less acute angle and less obliquely. On account of the oblique junction with the ileum, it usually is also asymmetrical, and in front is displaced to the right. The upper lip of valve is more regularly formed: it is a half-moon-shaped fold, projecting into the large intestine—a plica semi-lunaris. . . . The form of the opening of the valve appears as a fusiform slit, which is generally described as being horizontally placed."

But he refers to his Fig. 192 as proving that also an oblique position occurs. "Its length varies somewhat, yet one may assume it, at an average, at about 60 millimetres. . . . The free edge of the two valve lips is, in a fresh intestine, full and thick."

Poirier and Charpy[9], speaking of the valvula coli, remark (p. 326): "In the fresh state it appears in the form of a rounded eminence, projecting 10 to 12 millimetres, thick, oblong from front to back, flattened from above downwards, and perforated by a button-hole aperture in the centre. This opening, or ileal orifice, about 1 centimetre long and often less, is formed by two lips, one over the other—the one superior, the other inferior—slanting one towards the other and united by their anterior and posterior extremities to form commissures of the valvula. The orifice is generally oval, the left anterior angle is round, and the right posterior is acute. Sometimes the orifice is fusiform and its two angles are acute. It is ordinarily horizontal, and looks to the right, or to the right and forwards. Sometimes it is oblique, and Merkel[10] shows one almost vertical."

Spalteholz[6] (p. 523, Fig. 572) describes the valvula coli as follows: "At the upper limit of the cæcum, in the posterior part of the left wall, lies the opening of the small intestine within the valvula coli (valve of the large intestine). In the formation of this the terminal portion of the small intestine is invaginated into the cavity of the large intestine (see his Fig. 574). There thus arise two high folds, formed by the small and large intestines, the labium superius and the labium inferius of the valvula coli, of which the lower may be shorter than the upper. Both folds go over into one another at their ends, and surround the opening of the small intestine proper by their projecting margins. This opening is slit-shaped, and its longitudinal diameter is usually directed from the left and above to the right and downward."

In comparing the above descriptions one is struck by the dissimilarity of the description of the valve as described in the dried and distended and the fresh state respectively. If we accept the dried distended form as

valid, then it can at most only represent one phase—*i.e.*, when the cæcum is greatly distended, probably more than it ever is under natural conditions in the human body. The divergence in the measurements of the opening of the valve in the dried specimens is very striking. What also is to be noted is the uniform agreement in the direction of the valve in dried specimens, which is always horizontal. This raises the question whether the uniform horizontal direction of the valve in the dried condition is not due to the great stretching of the circumference of the bowel in forcible distension, as also is its great length in some specimens in the dried inflated series. In the sharp, paper-like appearance of the valve in the dried specimens we have obviously a marked difference to that revealed in ordinary dissection.

Imperfect Valve Forms.

In reading through the descriptions by various authors of the valve, in nearly every instance there are examples of descriptions of imperfect valves. Struthers[4] mentions several cases. Birmingham[2] has recorded a case of absence of the valve. Also he says[2]: "The size of the segments of the valve, as seen in the dried condition, varies considerably; they are sometimes very imperfect; and even the absence of both has been recorded. But here, again, there is danger of falling into error through examining the parts under such artificial conditions."

It is striking, in the above descriptions, to notice the want of uniformity in the valves examined. If the valve has any definite use in the human economy, it is strange that in cases where it is recorded as imperfect or wanting some peculiarity in the health of the individual during life should not have been noticed.

There are, then, according to the descriptions, marked differences, amounting, in the opinion of the above

anatomists (see p. 5; also Toldt), to loss of function because of them. But there is no record by any of the observers as to the length of time the subject from whom the specimen was obtained has been dead. This surely is of importance when we are dealing with living tissues, whose form depends partly on muscular tone and partly on the presence and tension of fluid in the tissues held only for a short time after death in them in the same manner as in life. It is possible that, in the cases in which the valve has been reported as imperfect or wanting, the apparent defect has been one of post-mortem change, due to relaxation of the tissues. Then the temperature and cause of death, with degree of putrefaction, would be important. This function of the valve (that of closing mechanically) may be satisfactorily performed by its oblique entry into the cæcum, as mentioned by Symington.[3] However, if this is the only function of the valve, we would expect that the lips of the valve being without function would have disappeared.

Annular Forms.

Many investigators describe annular forms which they have examined.

Poirier and Charpy,[9] in dealing with this matter, remark: "Sometimes one finds the ileo-cæcal valve of a circular type" (Charpy, Fig. 175).

Toldt[1] has observed examples in a fœtus and in the cat and in monkeys.

Also Bureau,[11] quoted by Poirier and Charpy,[9] says that in animals with large cæcum the valvula is an annular diaphragm pierced with a narrow orifice.

Struthers[4] (*loc. cit.*, p. 298) speaks as if the annular form was always seen at one stage during development. "In further stages (of development) the curtain goes round and round like the pyloric curtain without frenula."

C. Toldt,[1] speaking of abnormal cases, says: "In

another case, in a fœtus eight months old, the valve showed quite against all rule; both lips were very short, and passed arch-like into each other, so that the valve was almost circular. The frenula were completely wanting (Fig. 20). Such a valve cannot be capable of closing."

Later, in speaking of the cat, Toldt[1] remarks: "In the cat, on the other hand, where the termination of the ileum comes approximately vertical to the wall of the large intestine, there is no real valve to be seen, but only a slightly projecting annular swelling of the mucous membrane."

Here, then, is another form described by Toldt[1] as against all rule, though Bureau,[11] on the other hand, regards it as the form typical in animals with a large cæcum. This is another point where anatomists differ.

Microscopical Appearances.

In regard to the minute structure of the valve, Struthers[4] says: "There is want of evidence as to how far or whether at all in animals possessing an ileo-cæcal curtain (= annular fold) there is a sphincter muscle or any muscular structure beyond a few fibres of the circular coat of the intestine, seen in the flaps of the human ileo-colic valve."

Symington[3] says: "Each segment of the valve consists of two layers of mucous membrane, continuous with each other along the free margin, and including between them, besides the submucous areolar tissue, a number of muscular fibres continued from the circular fibres of the ileum and of the large intestine. The longitudinal muscular fibres and the peritoneal coat take no part in the formation of the valve."

Toldt[1] (quoted also by Poirier and Charpy)[9] has shown that the invagination includes not only the circular coat, which was known, but also the deep plane of the longi-

tudinal fibres of the ileum and of the large intestine. He says: "If one has prepared a specimen from an adult valve hardened in picric acid and alcohol, by making vertical sections in the direction of the entry of the small intestine, then the microscopical results show that the muscular sheet of the circular fibre layers, which enters from the large intestine and the ileum into each lip of the valve, are within the latter arranged into two sharply separated series, between which is intercalated a layer of longitudinally arranged muscular fibre bundles." (His Fig. 22 shows this relation under weak magnification.) "In the vicinity of the edge of the lip, where the two rows of the circular fibre bundles pass into each other, the longitudinal fibre layer disappears."

He further states that: "There can exist no doubt, therefore, that from the ileum, as well as from the large intestine, a certain portion of the longitudinal fibres passes into the lips of the valve, in order to run in them between the two layers of the circular fibre layer up to near the edge of the lip. . . . The longitudinal fibre layer, as well as each of the two layers of circular fibres, is of less thickness than the corresponding layers of the adjoining small and large intestinal walls. The submucous tissue upon the colic aspect of the lips of the valve is, in general, of much looser structure than on the ileal aspect. At the edge of the lip, however, there radiate from the united muscle layers stout connective-tissue strands through the submucous tissue up to the tunica propria of the mucous membrane, establishing a very firm union of both."

Nature of Function of Valvula Coli.

Cunningham,[8] Struthers,[4] Poirier and Charpy,[9] Piersol,[7] Gray,[14] etc., are all emphatic as to the function of the valve, —*i.e.*, by its mechanical structure to prevent the return of substances or fluids from the large intestine to the small.

According to Symington,[3] the function of the ileo-colic valve is to prevent the intestinal contents passing from the large into the small intestine. "Its valvular action is independent of muscular action, as air or fluid forced into the large intestine does not generally find its way into the ileum."

Struthers[4] says: "But the utility of the ileo-cæcal valve is precisely the opposite" (that is, to the sphincter action of the pylorus); "in its fully developed condition it is a mechanical valve proved to be so in the dead body."

As to the method of action, Cunningham[8] says: "The function of this valve is obvious. It is arranged that the free passage of materials from the ileum into the cæcum is in no way impeded; but when the cæcum becomes distended, and there is consequently a tendency to regurgitation, the frenula of the valve are put on the stretch, and the free borders of the segments are brought into firm contact. In this way reflux of the contents of the ileum into the cæcum is prevented, although it is well to note that the obliquity of the entrance of the ileum into the cæcum also exercises a very important influence in this direction."

Concerning the function of the valve, anatomists are practically unanimous. This is to allow of free flow from the small into the large intestine and check the return.

Functional Sufficiency of the Valve.

Dealing with the completeness of the valve action at the ileo-cæcal junction, we find great diversity of opinion. Presuming that the theory held concerning this valve is correct—*i.e.*, that the valve is placed in this situation to prevent reflux—then, if the method of action were merely mechanical, we might expect some uniformity in the results of experiments after death. There is, however, less uniformity in this respect than in others.

Birmingham[2] states: "In the great majority of cases, when in position in the body, the ileum is perfectly protected from such a return."

Poirier and Charpy[9] are emphatic concerning the incompetence of the valve. They say: "One has always considered this valvula like an impassable barrier preventing the return of the contents of the large intestine; therefore its name of the 'barrier of the apothecaries.' Most authors hold that it is always impassable as well for solids, liquids, and gases. (Fabrice d'Aquapendente, Riolan, Panizza, Sappey, etc.)

"Cruveilhier, on the contrary, after numerous experiments, concludes that more often the valve is not sufficient; the liquids and gases can overcome its resistance and return into the ileum. Numerous experiments have satisfied me that the opinion of Cruveilhier was well founded, and that the ileal valve is often, if not always, passed by gases, and even by liquids, injected into the large intestine."

From the above representative quotations the division of opinion concerning the competence and incompetence of the valve is seen. There is neither uniformity nor ability to satisfactorily demonstrate the action of a valve in this position, as in the veins or heart, when *in situ* or removed from the body. The resemblance to the valves in the circulatory system is more suggestive in the dried distended specimens with sharp, paper-like edges. However, the tendency is growing in modern textbooks to discard the dried distended descriptions and diagrams, or to accept them only with reservation.

Dealing with hardened fresh specimens, we find that these have thickened, rounded edges, which are considered to be approximated and closed by the operation of two factors—viz., the distension of the large intestine, causing traction on the frenula, and the obli-

quity of the entrance of the ileum. In spite of these factors, there seems a probability of regurgitation even in the living subject, as maintained by Poirier and Charpy,[9] especially until the frenula act.

Shape causing Incompleteness of Closure.

The orifice of the valve is regarded as a slit varying in shape and length. The method of closure is regarded as the apposition of the two lips controlled by the frenula. In reading the descriptions of the valve, one is struck by the differences of shape and size of the two lips of the valve, which are held to cause incompleteness of closure. Thus Birmingham[2] (Quain's "Anatomy") recorded a case of absence of the ileo-cæcal valve, and Struthers[4] has described several specimens in which the valve was imperfectly developed.

Piersol,[7] speaking on this point, states: "Much difference of opinion exists as to the completeness of the closure of the ileo-cæcal valve, and experiments do not agree. If the experiment of injecting water or air from the colon be performed *in situ*, the closure is more likely to be complete than if the parts have been removed. These experiments, however, do not represent the true condition during life, since the tonicity of the muscular fibres of the gut is lost, and in the opened abdomen the pressure of the viscera on the end of the ileum is less than normal. In life the valve probably is efficient."

Toldt[1] speaks on this point at some length (p. 63): "If one has, however, before one the cæcum of a new-born child or of one only a few months old, in the distended condition, the flattened, more or less wedge-shaped valve, provided with blunt-edged lips, projects on the dorsal wall of the cæcum into the lumen of the intestine" (in his Fig. 21). "The lower lip is considerably shorter than the upper one, its free edge more or less cut

out concavely, so that the valve edges by very moderate extension cannot come into touch. The valve, therefore, is not capable of closing."

P. 63: "In a similar case, in a full-time fœtus at birth, the valve had the usual form; both lips were, however, remarkably short. In another case, in a fœtus eight months old, the appearance of the valve was quite against all rule; both lips were very short and passed arch-like into each other, so that the opening of the valve was almost circular. The frenula were completely wanting" (in his Fig. 20). "Such a valve cannot be capable of closing. Similar conditions might also be the cause for the varieties of shape and development of formation of the valvula coli in mammals." Toldt[1] instances similar conditions in other mammals, as, for example, "in the dog, where the end of the small intestine is placed in almost the same direction as the beginning of the colon, and forms a very acute angle with the cæcum—a short, half-moon-shaped fold, which corresponds to the lower valve lip of man. An upper valve lip is not present. A quite similar appearance I have seen in some herbivora. In the cat, on the other hand, where the termination of the ileum comes approximately vertical to the wall of the large intestine, there is no real valve to be seen, but only a slightly annular swelling of the mucous membrane.

"I do not doubt that the differences of the valvula coli in adult man, especially as regard to form, size, and direction of the lower lip, which are not restricted in the slightest degree, depend upon the repeatedly emphasized slight divergencies in the developmental processes of the cæcum. These must, it appears to me, in considering the closing capacity of the valve, be taken into consideration more than has been done up to now. The fact that the valvula coli in the new-born infant, in the great majority of cases, proves itself insufficient, is in every case to be

traced back to the as yet incomplete formation. That means to the relative shortness and the half-moon-shaped limitation of the lower lip."

P. 66: "The fact also that the walls also in the adult, with contracted cæcum, show other relations of form than in the distended cæcum, and these relations quite analogous to what has been above described in the new-born child needs no further explanation."

From his observations I gather he considers the relations in the contracted cæcum of the adult and in the cæcum of the new-born child as analogous. Also that in these two forms the valve is incompetent, through the shape of the valve not allowing complete closure.

Debierre (*Lyon Med.*, 1885, p. 301, quoted by Poirier and Charpy[9]) holds that the ileo-cæcal valve is impassable only if its two valves are equal, or if the inferior one is the longer. It is insufficient when the inferior lip is a segment of a smaller circle than the superior lip.

If Toldt[1] is right, then in the new-born and in adults with contracted cæca the valve is incompetent through incomplete closure. It is to be presumed that the sole function of the valve comes into play when the cæcum is distended. Any function of the valve in regulating the flow onwards is assumed to be wanting, and the action of the valve is the purely mechanical one of preventing the regurgitation of the contents of the large intestine. Until the frenula are put on the stretch sufficient to close the valve, regurgitation may take place.

Valve Action due to Oblique Entry into the Ileum.

Cunningham,[8] speaking of the closure of the valve by the means of frenula, says: "In this way reflux of the

contents of the cæcum into the ileum is prevented, although it is well to note that the obliquity of the entrance of the ileum into the cæcum also exercises a very important influence in this direction."

Ambrose Birmingham[2] says, on this point: "There is little doubt, as pointed out by Symington, that the efficiency of the ileo-cæcal valve is largely due to the oblique manner in which the ileum enters or invaginates the cæcum; this oblique passage alone, as in the case of the ureter, piercing the wall of the bladder, would probably be sufficient to prevent a return of the cæcal contents."

Here, again, as in the question of completeness of closure, the sole function of the valve is considered to prevent regurgitation. If we are to regard the closure of the valve as a merely mechanical action, there is no doubt that this question of the oblique entry of the ileum has a very important bearing on the subject.

Function of Muscular Fibres in Valvula Coli.

A third factor has, however, been advanced as controlling or contributing to the closure of the valvular orifice—viz., a sphincter-like contraction of the circular muscular fibres around the orifice and in the valve segments themselves, after the pattern of the pyloric and internal anal sphincters.

The operation of such a factor has, however, by no means obtained general acceptance.

An occluding function of the muscular fibres is either wholly ignored by most anatomists or regarded as unimportant.

Poirier and Charpy,[9] however, in a note (p. 329, tome iv., 1901): "What is more, the valvula contains a muscular apparatus, feeble it is true, but who knows it is inactive?"

Bureau[11] (quoted by Poirier and Charpy,[9] in a note, p. 329) is emphatic. He says: "The mechanical occlusion is always imperfect, and is only completed by a muscular ring like that in the pylorus." Little notice has, however, been taken of this theory by anatomists.

Thus Symington[3] regards the operation of the valve as independent of muscular activity.

On this question Struthers[4] is most emphatic. He says: "In its fully developed condition it is a mechanical valve, proved to be so in the dead body. . . . There is want of evidence as to how far, or whether at all, in animals possessing an ileo-cæcal curtain, there is a sphincter muscle, or any muscular structure beyond a few fibres of the circular coat of the intestine seen in the flaps of the human ileo-cæcal valve. Again (p. 303): "Any little action the few circular muscular fibres in the valve can exert in the living body will be rather in the direction of tightening the valve."

Toldt,[1] however, described two circular fibre layers separated by a layer of longitudinal muscular fibre bundles, which, he says, are not as large as the corresponding layers in the small and large intestines. The relative thickness of the muscular layers would, however, depend on whether they were relaxed or contracted in the same degree in both the intestinal layers and the layers of the valve.

Also Keith[15] and Elliot[16] have advanced facts in support of sphincter action more recently.

Keith states:

1. That the ileo-cæcal junction is guarded by a muscular sphincter which has two purposes: (*a*) To regulate the flow of the bowel contents into the cæcum; (*b*) to prevent any regurgitation of the contents of the cæcum into the ileum. In this, its second function, the ileo-cæcal orifice may be aided by its lips being arranged to serve, more or less effectively, as a mechanical valve.

By means of paraffin-wax 100° C., Keith shows the sphincter action (pp. viii, ix, *re* the muscular fibres): "(1) That the muscular fibres surrounding the orifice form a series of racket-shaped loops, which, springing from the posterior frenulum, encircle the anterior angle of the orifice and return to end in the posterior frenulum. The posterior frenulum is the basis from which these fibres act."

When the fibres are thrown into heat contraction by the use of hot wax, the anterior margin of the orifice is drawn backwards, and the mucous membrane is thrown into folds which occlude the orifice.

2. In the upper ileo-cæcal valve the muscular fibres that enter it from the anterior and posterior frenula decussate.

In his Fig. 1, p. viii, and his description of the valve, Keith describes the sphincter as consisting of two parts: (Fig. 1, *c*) the lower valve forming the floor of the terminal part of the ileum, and the upper valve. He describes the closure of the valve as due to the pulling of the handle of the racket. Keith, in his conclusions, takes up a position midway between the mechanical valve and the valve of a purely sphincter action.

Elliott[16], arguing partly from a recording apparatus passed through the ileo-cæcal valve of etherized cats, and other experiments, states as part of his summary:

"The junction of the small and large intestine is controlled by a muscular sphincter, not a mechanical valve."

Keith supports his theory by dissection of the human subject, but neither Keith nor Elliot bring forward microscopical evidence.

Summary of Opinion regarding the Ileo-Cæcal Valve.

1. *Diversity of Opinion as to Typical Form of Valve.*—From consideration of the two types of description—

(*a*) of the distended and dried type, and (*b*) of the fresh, hardened specimens—of the ileo-cæcal valve under the headings mentioned, what strikes one is the want of uniformity of opinion on almost every point. In regard to no other organ of the body is opinion more divided. There is the greatest difference between the appearance of the dried specimen and the fresh. Though some observers would have us believe that the condition and relations of the parts are little if at all altered by dry preparation (Struthers,[4] Parsons,[5] p. 2), others (*e.g.*, Toldt[1]) condemn the dried forms altogether. In the description of details the same divergence of opinion prevails.

In reference to the construction of the valve, authors are agreed that in every case the ileo-cæcal valve consists of two folds, flaps, or lips, and frenula, which prevent the lips from being driven back into the ileum. Departures from the above form are considered abnormal. While this is so, authors differ widely in their description of the constituent parts of the valve, in the relative size of the two lips, in their shape and direction.

The appearance of the opening varies greatly, ranging from the long slit described in the dried specimens, through fusiform and pear-shaped forms, down to the small opening described by Bureau.[11] From the above it appears there is no fixed type of valve described and accepted by anatomists.

2. *The Frenula Valvulæ Coli.*—Frenula, or retinacula, are ordinarily described as an essential part of the valve, acting, when put on the stretch, by distension of the cæcum, in closing the valve.

3. *Sufficiency or Incompetence* of the valve is under dispute. The opinion of anatomists is based on the condition after death. However, we do not find uniformity on this point. Some anatomists consider the valve competent after death (Struthers,[4] Parsons[5]), while

others consider that even during life the valve is incompetent (Poirier and Charpy[9]). Several anatomists regard incompetence as resulting from the completeness of closure due to variations of shape or to defects in the construction of the valve. Toldt[1] speaks of loss of power to close the valve in the new-born and in adults with contracted cæca. All valves which do not conform to the bilabiate type with frenula are regarded by various anatomists as incompetent. Circular forms are thus ruled out as imperfect. Additional factors contributing to the competency of the valve are recognized by authors—*e.g.*, Symington[3] (*loc. cit.*)—in the obliquity of the entry of the small intestine, and in the position of the valve and its surroundings in the body.

4. *Method of Closure.*—The method of closure by means of which competence is obtained, is usually regarded as either wholly or predominantly due to the passive mechanical action of the valve, and to be independent of sphincter action due to muscular fibres in the valve.

5. *Musculature of the Valve.*—Muscular fibres are recognized and described by all anatomists as occurring in the valve.

Toldt,[1] who describes the entry of the longitudinal fibres from the corresponding intestinal musculature into the substance of the valve between the two circular muscle layers, says, however: "The longitudinal fibre layer, as well as each of the two layers of circular fibres, is of less thickness than the corresponding layers of the adjoining small and large intestinal walls." In his diagrams of sections of the valve he shows the lip of the valve as elongated and slender, and the muscle layer thin. Symington[3] denies the presence of longitudinal fibres altogether.

6. *Function of Muscular Fibres in the Valve.*—A genuine sphincter action by the circular muscle fibres is not

generally admitted by modern anatomists. Even Toldt,[1] who has demonstrated the longitudinal fibres, describes both circular and longitudinal muscle fibres as less in thickness than corresponding layers of the adjoining small and large intestine. The general opinion of modern anatomists is that the muscular fibres are unimportant, or only serve to tighten the valve by frenular traction.

As an exception to the above are Keith[15] and Elliott[16] (p. 20).

POINTS TO BE DECIDED.

1*a*. Dry versus Fresh Specimens.—

1. What is the normal appearance of the valve ?
2. Is the valve normally competent ?
3. What is the function of the valve ?
4. What is the value of the muscular fibres ?

For the purpose of this thesis only fresh specimens, removed as soon as possible from the body and preserved in 10 per cent. formalin, will be used. In order to obtain these the colon is cut across 8 centimetres roughly above the valve. The ileum is cut across 8 centimetres below the valve, and the cæcum, with the attached small and large bowel, after washing, is put at once into a large deep bowl containing 10 per cent. formalin.

However, Waterston[13] shows that: "The effect of formalin upon the intestine is, therefore, precisely similar to that which it produces upon the arteries, which has been so fully and clearly established by McWilliam . . . viz., that, owing to the persistence of the irritability of the muscular coat, contraction is produced in length and in width."

Fresh Specimens described in Many Forms.—The descriptions of fresh specimens by different observers vary. There is no uniformity. It is obvious that in order to describe the valve, the best time to do so is during life

or as soon as possible after death. The loss of turgescence, due to evaporation and displacement of fluid in the tissues, also the loss of muscular tone, rapidly causes changes in the appearance of the parts, which become more marked as putrefaction advances. Another point to be observed is that in cold weather the form of specimens is preserved longer than in hot weather. The want of uniformity in the descriptions of fresh specimens by observers makes it probable that the ileo-cæcal valve changes soon after death, and that each observer's descriptions of the normal appearance are of certain phases of post-mortem change.

The regular form accepted by observers—*i.e.*, two lips with frenula—must be considered with those considered abnormal, notably the forms described as annular and not having frenula.

1. What is the normal appearance of the valve ?

In regard to Competence or Incompetence of the Ileo-Cæcal Valve.—2. Is the valve normally competent ?

Considering the Function of the Valve.—The accepted function of the valve is to prevent reflux from the large to the small intestine. This theory is founded on the structure of the cæcum and small intestine and its behaviour to fluid distension after death. It is the direct outcome of the mechanical theory of the valve, and leaves peristalsis out of the question. However, both the pylorus and internal anal sphincter valves in an analogous position to the ileo-cæcal have the function of regulating the discharge of contents of the digestive tract above them when its digestive function is completed.

3. What is the function of the valve ?

Considering the Muscular Fibres, both Circular and Longitudinal, contained in the Substance of the Valve.—

4. What is the value of the muscular fibres ?

PART II

OBSERVATIONS ON LIVING SUBJECT

Ileo-Cæcal Valve.

In May, 1905, I had under my observation a case where there was an artificial anus in the cæcum 8 centimetres long. This artificial anus was on the anterior wall of the cæcum 8 centimetres roughly from the head of the cæcum.

Cæcum.—The cæcum was collapsed, and its interior was occupied by pink folds of mucous membrane. The interior could be observed, also the ileo-cæcal orifice when it came into view.

Colon.—The interior of the colon appeared paler than the mucous membrane of the mouth, being more of a pink colour. Encircling the walls at right angles to the long axis of the bowel, about every centimetre, were folds of mucous membrane, similar in appearance to the valvulæ conniventes of the small intestine, only somewhat larger. The interior was smooth, except where the mucous membrane lay in folds. There was no appearance of sacculation in the wall of the cæcum or colon.

Ileo-Cæcal Valve.—Through this aperture in the cæcum the ileo-cæcal orifice was sometimes seen. Ordinarily covered by the loose folds of mucous membrane of the empty colon and caput cæcum coli, and obscured still further by fluid fæces, the ileo-cæcal orifice would discharge fæces without being seen. Occasionally when peristalsis was more active than usual, or when the interior of the cæcum was irrigated by warm water, a papilla about 1·8 centimetres in diameter, and projecting

about 1 centimetre from the wall of the cæcum, could be seen. The mucous membrane covering the papillary eminence was of the redness in appearance of the inside of the lips, smooth, and glistening, without folds. In appearance, colour, and contour the papilla was in sharp contrast to the adjacent wall of the colon and caput cæcum coli. The eminence was smooth, scarlet, tense, and rounded, with a dimpled orifice at the summit, in appearance resembling half a scarlet cherry, whereas the wall of the colon and cæcum was thrown regularly into folds, which ended abruptly at circumference of the papilla.* These folds were of a pink colour, collapsed, showing no tension, and flat. About the orifice, on the summit of this mammillary eminence, there was no appearance of loose or redundant mucous membrane. The mucous membrane was drawn tight over the firm swelling forming the papilla. There was an orifice in the centre of the papilla, from which five radiating corrugations ran out for about 6 millimetres ($\frac{1}{4}$ inch). These corrugations would disappear as described later.

The method of appearance of this papillary eminence was as follows:

When peristalsis was sluggish, the papilla remained hidden under the folds of mucous membrane, and the fluid fæces welled up from the colon and the caput cæcum coli. When first observed (as the papilla moved towards the surface) in the cavity of the artificial anus, the form of the papilla would not be seen, only a depression in the loose mucous membrane showing where the orifice was. When peristalsis was slight, the papilla merely appeared gently through the superimposed mucous membrane, its form becoming more distinct in proportion to the strength of peristalsis.

When peristalsis was active, the papilla emerged from

* There was no reason to consider the scarlet colour of the papilla to be due to pathological congestion.

the folds of mucous membrane, shifting its position by a series of rhythmical movements. Each successive movement produced displacement of the papilla, both in longitudinal, transverse, and antero-posterior direction, so that under observation it appeared to trace a series of sigmoid curves. The course of this displacement of the papilla was upward, proceeding by lateral sigmoid movements, at the same time advancing and receding from the artificial anus. This upward movement was limited to about 8 centimetres from the lower end of the artificial anus. When the papilla reached the height of its excursion, it would remain for about one second and then slowly collapse into the caput cæcum coli. This movement was, however, of a somewhat jerky nature, most marked when each rhythmical movement gave place to its successor. The diameter of the completed circle of the curve of each sigmoid figure would have been about 4 centimetres. As the papilla passed the lower end of the artificial anus in the course of its upward movement, the wall of the cæcum was seen to be pushed forward, and then receded in rhythmical manner, obviously under the influence of movement of the termination of the ileum. The rhythmical, undulating movements of the papilla were of peculiar sinuous nature, as might be those of a snake whose head was fixed in cotton sheeting.

The direction of the orifice was from the left and back to the right and slightly to the front of the body during quiescence of the main eminence. It was at right angles to the wall of the cæcum and colon. During the movements of the papillary eminence the orifice would point upwards, downwards, to right and left during its excursion.

The area of the papilla would be seen to enlarge at regular and rhythmical intervals, becoming at the same time less prominent. *Pari passu* with the enlargement of the papilla the orifice would open, apparently by the relaxation of the circular muscular fibres, and semi-fluid fæces, about 1

drachm, would be observed to emerge from the opening with a force varying with the strength of the peristalsis. The movements observed appeared to represent the terminations of the peristaltic waves projected along the small intestine. The rhythmical ejection of the semi-fluid fæces was accompanied by a vigorous contraction of the area of the papilla and its prominence and firmness increased as the orifice closed. During excitement the rate of these discharges would be about every second; or if the excitement was less, about every two seconds. When excitement was less, the jets would be less frequent. At the time of this discharge the corrugations about the opening in the centre of this papilla would disappear. Ordinarily this function was performed under the overlapping folds of the mucous membrane lining the cæcum; but when peristalsis become vigorous, the papilla would work its way up through the loose folds of the mucous membrane and come into view.

While peristalsis was moderate, the orifice of the papilla would open sluggishly, and the fæces would be discharged sluggishly; but while peristalsis was active, the papilla would open quickly and the fæces would be ejected in jets, after which the papilla would close again smartly. At times flatus would escape, the papilla opening to allow its passage, or fluid mixed with flatus. The sphincter action was, however, perfect in control, and would allow nothing to pass without relaxation, not even flatus.

The exercise of the functions described above caused no sensation to the patient; the papilla was firm and elastic to touch, like a rubber ball of 2 centimetres in diameter, tender especially when the finger or instrument was placed on the aperture in the centre of the papilla. The papilla was not connected by any bands, ridges, etc., to any part of the interior of the cæcum. There was no appearance of frenula. I endeavoured to pass a No. 12 English catheter through the orifice, but did not succeed,

partly on account of the resistance to dilatation, which was considerable, but more on account of the tenderness, which soon became unbearable to the patient. The same thing occurred when I tried to dilate with my index-finger. The sensation was similar to trying to dilate the anus, an elastic resistance, yielding somewhat, and then recoiling. I was soon obliged to desist on account of tenderness.

The orifice of the appendix was not observed, probably on account of this case having been an inflammatory one. I have had subsequent opportunities of verifying, by palpation of the unopened cæcum during operation in patients under very light ether anæsthesia, the occurrence of the same characteristic rubber-ball feeling of the mass at the ileo-cæcal junction, the anæsthesia being too light to abolish peristalsis. In these cases at the ileo-cæcal junction these was a feeling of an elastic mass, about 2 centimetres in diameter.

Chloroform.—Under deep anæsthesia the firm elastic mass altered and the dimpled orifice relaxed. Instead of a mass there was now a slit-like orifice 2½ centimetres long, through which the index and middle fingers were readily passed. The circular muscular fibres could now be felt as thickened bands at the margin of this orifice. There was no appearance of projecting flaps of mucous membrane, the edges of the slit being almost flush with the mucous membrane of the cæcum. The direction of this slit was upward and inward, at about the angle of 45 degrees to the transverse plane of the body.

Peristalsis.—On account of the aperture forming the artificial anus in the cæcum, peristalsis probably was less marked than usual. However, two sorts of peristalsis were noticed—one, the ordinary vermicular type, in which the muscular wall every centimetre in the long axis of the cæcum would contract in waves from below upwards. The second form was more complex. It is

with diffidence that I mention the following, as I only observed it once. I mention it, however, because of its possible bearing on what follows.

In the region of the cæcal wall, roughly 6 centimetres from the papilla, four small dimples appeared on observation, the force causing them apparently originating in the muscular layer of the cæcum. These four dimples formed the corners of a rhomboidal figure if they were connected by lines. The first two to appear were about 4 centimetres apart along the circumference of the bowel, the other two about 3 centimetres nearer the head of the cæcum 4 centimetres apart along the circumference of the bowel. Immediately these four appeared there was a twitch, and the four corners approached as if by the contraction of a muscle connecting them acting like a purse-string. This immediately relaxed, and the depressions of the corners disappeared. As probably connected with or dependent upon this type of peristalsis, it should be mentioned that while observing the interior of the cæcum during the period that the valvular papilla was not visible, a pencil of firm fæces, 7·5 millimetres in diameter and 6 centimetres in length, was one day seen to be pressed out of an apparent round orifice in the wall of the cæcum. This was pressed out with considerable force in a direction at right angles to the surface of the bowel, evidently moulded by the circular aperture through which it emerged. After the fæcal mass had been extruded, no orifice, however, could be discovered, and the spot where it had come from had the same appearance as the rest of the intestine. The nurse in charge told me she frequently observed this appearance in different positions of the colon, and it had no relation to the site of the ileo-cæcal orifice, but was noticeable in an area nearer the rectum. No inspissated fæcal masses were ever noticed coming from the caput cæcum coli, only

semi-fluid similar to that coming through the ileo-cæcal orifice. Also it was observed that the pencil of fæces was not fluid like that coming through the opening of the ileo-cæcal orifice, but about the firmness of the ordinary fæces. Through the upper end of the artificial anus formed fæces could be observed lying in the ascending colon, and made up of lobulated inspissated portions, resembling in appearance fæces passed *per anum.*

Enemata.—Douching the interior of the cæcum with hot water at once increased the peristalsis of the large, but more markedly of the small, intestine. In cleansing the area with the douche, it would frequently become soiled again at once from the activity in the escaping jets of fluid from the ileo-cæcal orifice. Daily the patient passed fæces by the rectum. It was smaller than the usual motion because of the loss through the artificial anus. In lobulation and other characteristics it did not show anything abnormal. The lower end of the bowel was every few days emptied by means of the enema. A very small one was needed, even one of 1 pint partly flowing through the artificial anus. This would at once lead to increased peristalsis in the small intestine and less markedly in the large. The increase was most marked when the ileo-cæcal orifice was irrigated. Probably enemata act not only as a foreign body, but as a stimulus to the peristalsis not only of the large intestine, but also of the small intestine.

Analogy.

In considering the known openings between one portion of the intestinal tract and another, we find that the arrangement in the pylorus and the internal anal sphincter is similar to that at the ileo-cæcal orifice. There is the outlet of a tube controlled by strong circular, muscular fibres, which by their concentric contraction keep the aperture closed till the condition of the contents and

peristalsis cause a reflex which relaxes the circular fibres, allowing the aperture in each case to open and discharge more or less of their contents. In the anus this reflex is controlled largely by the will, the voluntary muscles in that region being called in to assist. Also in the anus the act is felt, but in the pylorus and ileo-cæcal sphincter the action is automatic, and no sensation is experienced. In arrangement and function the ileo-cæcal valve is a sphincter, not a valve, as in the heart or the veins. When the band of muscle surrounding the orifice of the ileum contracts, it must lead to a concentric contraction of the ileo-cæcal aperture. It could not admit when tonically contracted of a slit-like opening as seen post mortem or under chloroform. The circular muscular fibres when contracting must act as a sphincter concentrically closing the orifice.

Physiological Deductions.

From the facts in this case it appears probable that the lower end of the ileum is controlled by a purely sphincter-like action of the circular intestinal muscle of the orifice. In this case, when under chloroform, nearly all appearance of raised mammillary edges of valve disappeared, leaving merely a slit in the colon wall. From this it would appear probable that post-mortem appearance of valvular edges is due to muscular tone not being lost in fresh specimens (as is the case under chloroform), formalin probably accentuating contraction of the muscle in the valve mammilla.

In dried specimens the various segments of valves described are probably due to the empty hemispherical dome of special mucous membrane which covers the papilla eminence when firm and contracted, being somewhat distinct from that lining the cæcum and colon, is not stretched by inflation and drying so much as their

mucous membrane, but appears as two cusps due to the lateral stretching.

Through this sphincter the semi-fluid contents of the ileum are discharged automatically about a drachm at a time, at a rate depending on the degree of peristalsis. Flatus in varying quantities is also discharged automatically. The caput cæcum coli (possibly owing to the injury) was largely passive under observation. Below the caput cæcum coli a process of taking the semi-fluid contents discharged through the ileo-cæcal valve into pouches seems probable. In these pouches the semi-fluid contents are inspissated and then pressed out of these pouches into the lumen of the bowel as pencil-like bodies which, being pressed together, form the characteristic lobulation observed in the fæces.

The question as to where the origin controlling the reflex of the sphincter arises is not a simple one. After purgative medicines, particularly salines, the valve was seen to be active in function *pari passu* with the activity of the peristalsis, the actual opening of the valve seeming to be the final part of a wave of peristalsis along the ileum. This wave of peristalsis in the ileum could be traced, obscurely it is true, beneath the more quiescent cæcum. Whether the reflex was due to the continuation of the wave of peristalsis along the ileum or to a reflex caused through increase in the contents of the ileum at its termination pressing upon the sphincter, or both, it is impossible to say, though probably both causes come into play. However, that the above is not the only cause of the exercise of the function of the valve was shown by irrigating the interior of the colon and cæcum with hot water. When this was done, peristalsis in the ileum was noticed to be increased both in rate and force, and *pari passu* the function of opening and closing the sphincter accompanied by ejection of fluid fæcal matter. This

phenomenon was most active when the ileo-cæcal valve mammilla was irrigated. The probability, then, is that the origin of the reflex controlling the sphincter at the ileo-cæcal orifice is twofold, arising, on the one hand, from the ileum, being either the termination of a wave of peristalsis, or due to increase of the contents of the termination of the ileum or both causes coming into play; on the other, arising from a stimulus to the mucous membrane of the cæcum, which, as we have shown in irrigation with hot water in the human subject, increases the peristalsis of the ileum and ejection of fæcal matter through the sphincter.

ILEO-CÆCAL VALVE IN THE DOG.

To obtain a specimen while peristalsis was active, a dog was shot. The body was at once opened and the valve examined. Through the bowel wall a distinct thickening was made out. On opening the colon and following it down to the position of the ileo-cæcal valve, the valve was seen to be circular in form and completely closed. From the centre, stellate corrugations were seen to run like the spokes of a wheel. On cutting through the valve from the colon to the ileum, a distinct ring of muscular tissue was severed, the cut ends of which retracted forcibly, leaving a wide gap. In this specimen, therefore, it was evident that there was a strong ring of muscular tissue at the ileo-cæcal junction forming a sphincter. The cut ends of the sphincter were seen at the sides of this gap continuous with a wedge-shaped ring of muscular tissue passing round the bowel at the ileo-cæcal junction. The ring of muscular tissue was in a state of contraction. On stimulating one of the cut ends, however, the sphincter would immediately contract more strongly, the wedge of muscular tissue round the lumen of the bowel becoming shorter in length, thicker in width, and less curved.

From the behaviour of the living subject (p. 29) under chloroform, it is to be gathered that dogs killed by chloroform are not suitable for study of the condition during life, because of the complete muscular relaxation caused by this drug.

A second dog, male, weighing 16 kilogrammes, was shot. On opening the abdomen, peristalsis was noticed to be active. The ileum was cut across at a distance 3 centimetres from the large bowel. The cæcum, which was distended, was cut so as to expose the ileo-cæcal valve, and removed from the body. At once the specimen was placed into warm saline.

On examining the ileo-cæcal orifice of this specimen, which is shown by Photograph E (*a*), about natural size, and Photograph E (*b*), an enlargement of Photograph E (*a*), it will be seen to consist of a mammillary eminence, with an orifice in the centre tightly closed. In this specimen the diameter was 9 millimetres. From the centre five radiating grooves will be seen to run outwards, with lobulated, wedge-shaped masses between them. These grooves, and the corrugated lobules between them, are evidently caused by the contraction of a sphincter muscle throwing the mucous and submucous tissue into folds. The valve mammilla is seen as a hemispherical mass 9 millimetres in diameter, truncated on the summit. In the photograph the grooves are exaggerated by the shadows due to the light coming from the side. Comparing the specimens shown with that seen during life and Specimens 1, 2, and 11, we see a marked resemblance.

In the human being during life the mammillary eminence was more hemispherical, the surface being less truncated; also the five grooves were less marked. However, in partial relaxation in the human subject, the appearance was more like the specimen shown of the dog.

The mammillary eminence of the ileo-cæcal valve still in contraction was removed from the cæcum and put into 10 per cent. formalin.

Peristalsis of the Cæcum of the Dog.

Although it does not enter into the subject of this thesis, a note on the peristalsis of the cæcum of the dog will be made here.

When the cæcum was put into warm saline, peristalsis remained active for some minutes. The cæcum was moderately distended. It was noticed that, as well as the vermicular peristalsis, another form of peristalsis was present. This peristalsis was due to contraction in the longitudinal muscular bands on the opposite sides of the cæcum. Equal lengths of the longitudinal muscular bands, not exactly opposite to each other, would contract simultaneously. This form of peristalsis would run in a wave from the caput cæcum coli downwards, imparting a zigzag churning motion to the contents of the cæcum.

DESCRIPTION OF THIRTY-TWO HUMAN SPECIMENS HARDENED IN FORMALIN.*

A. 1. Presents the ileo-cæcal valve as a rounded, projecting, mammillary eminence. The opening is almost closed. It is somewhat stellate in form, being encroached upon by elevations of the mucous membrane lining the lumen of the valve. The apparent opening is 8·0 millimetres, but is merely a depression on the surface of the mammilla. There are no lips present.

Frenula, not present.
Vertical diameter of mammilla, 1·8 centimetres.
Transverse diameter of mammilla, 1·9 centimetres.
Post-mortem, six hours after death.
Average temperature of room at time of death, 50° F.
Sex, male.

* See Plates, Figs. 1-32.

2. Presents ileo-cæcal valve as a rounded, projecting mass, with an irregular stellate opening, 1 centimetre apparently in width in widest part, but the apparent opening is seen to be merely a furrow in the circular eminence. Lumen of the valve circular and almost closed.

Frenula, not present.
The mass projects 9·0 millimetres above colon.
The mass projects 5·0 millimetres above cæcum.
Vertical diameter of the mass, 1·8 centimetres.
Transverse diameter of the mass, 2 centimetres.
Post-mortem, six hours after death.
Average temperature of room at time of death, 50° F.
Sex, male.

Two Exhibits: Explanations of Photographs of Microscopical Slides of Specimen 2.

B. Horizontal section of mammilla close to base of the process, enlarged about 6 diameters. The section is irregularly oval, continuous with the posterior frenulum, and less markedly with the anterior frenulum.

The lumen (*l.*) is seen to have its oval form encroached upon by several projections of the mucous membrane of the lumen (*m.m.l.*) and the submucous tissue of the lumen (*sub.m.l.*). There is a marked amount of lymphoid tissue (*lym.t.*) under the mucous membrane. The muscularis mucosæ is seen to be present. In the submucous tissue of the lumen are seen many bloodvessels.

Next in order comes the muscular coat. This is seen as an irregularly oval ring, roughly midway between the mucous membrane of the lumen (*m.m.l.*) and the mucous membrane of the mammilla (*m.m.m.*). It is seen in this section to be continuous at the extremes of the oval, with muscular fibres (*m.f.*) running into the so-called frenula. This is most marked at the postero-external edge. At one

part, through an imperfection of the section, the muscular tissue is broken. Opposite this point the muscular ring can be seen to consist of three layers—namely:

(1) The internal circular muscular layer of the valve mammilla (*i.c.m.v.*), seen as long transverse strands.

(2) The longitudinal muscular layer of the valve mammilla cut across and seen as a series of dots (*l.m.v.*).

(3) The external circular muscle layer of valve mammilla (*ex.c.m.v.*) cut parallel to course of the muscular fibres, seen as long strands.

The muscular ring is seen to vary in thickness, possibly on account of the obliquity of the line of section. Outside the muscular ring is seen the submucous tissue of the valve mammilla (*sub.m.m.*). This is seen to contain many bloodvessels. The mucous membrane of the valve mammilla is seen cut vertically at the upper and obliquely at the lower part of the valve mammilla. Muscularis mucosæ is well seen.

C. A micro-photograph of part of a vertical section of the valve mammilla, enlarged about 100 diameters.

(*a*) The internal circular muscular coat of the valve mammilla (*i.c.m.v.*) cut across the fibres.

(*b*) The longitudinal muscular layer of the valve mammilla (*l.m.v.*), running vertically between the other two layers and represented by several strands, the line of section being parallel with the course of the muscular fibres.

(*c*) The external circular muscle layer of the valve mammilla (*ex.c.m.v.*) seen to be considerably thicker than the corresponding internal circular layer.

Physiology.

These two sections (*a*) and (*b*), represented by Photographs B and C, have most important bearing on the condition as described during life. Here it is shown there exist in the valve mammilla two circular sphincters,

separated by a longitudinal muscular sheet. The outer sphincter is thicker than the inner. The longitudinal muscular layer is thin, but still seen to be represented by several strands.

The effect of the contraction of the two circular layers is obvious—to close the opening by their sphincter action—the action of the fibres of the longitudinal sheet being continuous with the corresponding layers of the small and large bowel, and, taking purchase from them, would be to open the orifice of the valve mammilla. This arrangement of circular and radiating fibres, governed by the sympathetic system, permits of the automatic regulation of the flow of the contents of the small intestine through the valve mammilla, and prevents regurgitation from the large bowel. That this sphincter could be overcome by forcing water into the large bowel by the anus is probable, but the force would need to be considerable, as instanced in report of case during life by firm pressure of an instrument and the finger not overcoming it (see pp. 28-29). The rapidity of the opening and closing of the valve mammilla was shown to vary considerably, according as to whether peristalsis was active or sluggish. The action of the circular fibres of the ileo-cæcal junction in the position of the frenula is probably to assist in opening the valve by their contraction, thereby giving purchase to the contraction of the longitudinal muscular layer of the valve mammilla.

The encroachment on the lumen of the valve mammilla by folds of mucous membrane, with submucous areolar tissues, in Photograph B, is due to the incomplete relaxation of the circular muscular coats after death. The action of the circular coats in closing the lumen would also cause the mucous membrane surrounding it to be thrown into folds. These folds seen in Photograph B of the mucous membrane of the lumen correspond to the stellate lobulation seen at the orifice of valve mammilla in its

round form—*e.g.*, Specimens 1 and 2—as well as in the description of case during life (pp. 25-26).

3. Shows the ileo-cæcal valve as a thick, fleshy eminence, merging into thick, markedly elevated frenula at each side. The opening is transverse, and shows marked lobulation of the upper lip and of the lower to a less extent.

Opening, 2·4 centimetres. Continuous with the lumen of the bowel.
Frenula, marked and thick.
Upper lip projects 1·2 centimetres above colon.
Lower lip projects 1·5 centimetres above cæcum.
Vertical diameter of eminence, 1.4 centimetres.
Transverse diameter of eminence, 3·2 centimetres.
Post-mortem, twenty-four hours after death.
Average temperature of the room, about 50° F.
Sex, male.

4. Shows the ileo-cæcal valve as an elevated oval mass, with a gaping opening.

Opening, elongated 2·2 centimetres.
Frenula, well marked.
Upper lip flush with the colon.
Lower lip, 3 millimetres above the cæcum.
Vertical diameter of the mass, 1·4 centimetres.
Transverse diameter of the mass, 3·6 centimetres.
Post-mortem, twenty-four hours after death.
Average temperature of the room, about 55° F.
Sex, male.

5. Presents the ileo-cæcal valve as an eminence continuous with the frenula, and forming with them a partition between the colon and cæcum. The mucous membrane is everted, and the lips of the valve show slight lobulation.

Opening, 1·6 centimetres.
Frenula, marked.

Upper and lower lips flush with and continuous with partition formed between colon and cæcum.
Vertical diameter of the eminence, 1 centimetre.
Transverse diameter of the eminence, 2·7 centimetres.
Post-mortem, thirty-six hours after death.
Average temperature of the room at time of death, 50° F.
Sex, male.

6. Shows the ileo-cæcal valve less prominent; the opening of the valve is at an angle of nearly 45 degrees.

Opening, 2·2 centimetres continuous with the ileum.
Frenula, well marked.
Upper lip flush with the colon.
Lower lip, 3 millimetres above cæcum.
Vertical diameter, 1·2 centimetres.
Transverse diameter, 3 centimetres.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 50° F.
Sex, male.

7. Presents the eminence of the valve less regular than usual.

The *Opening* is elongated and irregular; it is transverse, 2·5 centimetres.
Frenula, marked.
Upper lip, 3 millimetres above colon.
Lower lip, 4 millimetres above cæcum.
Vertical diameter of eminence, 1·5 centimetres.
Transverse diameter of eminence, 3·2 centimetres.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 55° F.
Sex, male.

8. Shows a specimen in which the cæcum has been inverted to show the eminence of the valve better. This

has caused the valve to be pulled transversely, and an exaggeration of the outer frenulum.

The *Opening* is seen to be irregularly oval, with marked lobulations in the lumen of the valve.
Opening transverse diameter, 9 millimetres.
Upper, 3 millimetres above colon.
Lower, 7 millimetres above cæcum.
Frenula, proper, not marked, but the cæcum being partly everted creates folds at position of frenula.
Upper lip, 3 millimetres from colon.
Lower lip, 4 millimetres from cæcum.
Vertical diameter of eminence, 1·1 centimetres.
Transverse diameter of eminence, 1·9 centimetres.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 50° F.
Sex, male.

9. Presents an elevated mammilla, with transverse elongated opening, showing lobulation along the lips.

Opening, elongated, transverse, 1·9 centimetres.
Frenula, marked.
Upper lip, 8 millimetres above colon.
Lower lip, 5 millimetres above cæcum.
Vertical diameter of eminence, 1·7 centimetres.
Transverse diameter of eminence, 3·2 centimetres.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 55° F.
Sex, male.

10. Shows an elevated valve projection elongated transversely and running into frenula.

Opening, 2·3 centimetres.
Frenula, marked.
Upper lip elevated above the colon, 4 millimetres.
Lower lip elevated above the cæcum, 5 millimetres.

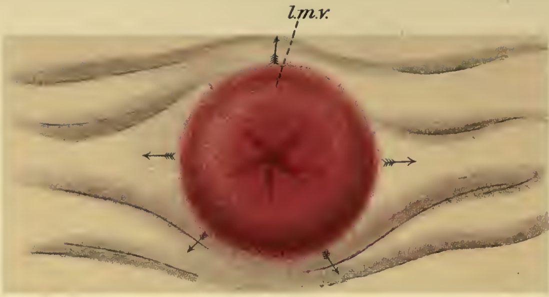

DIAGRAM I.—To show the appearance of valve during life and the action of radiating longitudinal m. fibres.

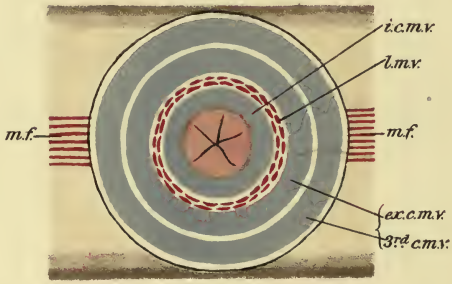

DIAGRAM II.—To show valve mammilla cut across the base in a condition of firm contraction. The circular muscle bundles are shown blue, the longitudinal fibres red. Also the fibres in the position of the frenula are red.

Cf. also DIAGRAM IV. for vertical section of papilla, also Photographic Plate D.

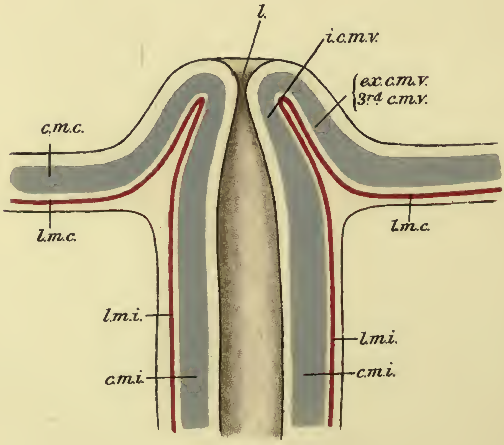

DIAGRAM III.
Circular muscular tissue blue. Longitudinal red.

Vertical diameter of valve, 2·2 centimetres.
Transverse diameter of valve, 3·4 centimetres.
Post-mortem, twenty-six hours after death.
Average temperature of the room, 60° F.
Sex, male.

Plate D.—Photograph of Microscopical Section of Specimen 11 *enlarged about* 6 *Diameters.*—The valve mammilla was cut through its diameter vertically in the direction of the entry of the small intestine. The left half of the valve mammilla is cut truly; the right side is obliquely cut. The lumen of the valve mammilla is seen to be encroached upon by a columnar fold of mucous membrane. The orifice of the lumen is seen as a cup-shaped depression separated from the lumen by a bridge of submucous tissue. It will be observed that the lumen runs the whole length of the mammilla of the valve, except the bridge of tissue separating it from the orifice. At its lower end the lumen is seen to end at the wall of the ileum, which here forms a shelf.

The submucous tissue is seen to contain many blood-vessels. To understand the muscular coat it is necessary to represent it diagrammatically. Diagram III. represents the muscular coat of the small and large intestines continued into the valve mammilla, with the corresponding muscular layers continued through it and meeting at the apex of the valve.

The circular muscle layer from the large intestine forming the external circular muscular layer of the valve mammilla (*ex.c.m.v.*).

The circular muscular layer of the ileum forms the internal circular muscular layer of the valve mammilla (*i.c.m.v.*). The longitudinal layer from the large and small bowel passes into the valve mammilla between these.

The third muscular sphincter layer (*3rd c.m.v.*), to be

described later, has purposely been omitted for the sake of simplicity. This layer is probably a reduplication of the external circular layer of the valve mammilla.

Diagram IV. is drawn to illustrate the muscular layers shown in Photograph D of Section 11. Outside, the external circular muscular layer of the valve mammilla is shown, extra fibres, as in the photograph, forming a third circular coat (*3rd c.m.v.*).

Diagram V. is to explain the position of the muscular coats in Photograph D. This photograph shows how the ileum forms a shelf encroaching on the lumen of the ileum, which shelf is cut obliquely across at the lower part of the lumen of the valve mammilla. This explains the reason that the bowel is cut transversely across the section, and the corresponding coats of the large and small bowel are seen continuous with the external and internal coats of the mammilla of the valve. The longitudinal coat of the small and large bowel respectively is seen to enter the valve mammilla.

Diagram VI. is intended to show the resulting form of a section cut in the direction of the arrows seen in Diagram V. at right angles to its surface. The shelf (*s*) is shown in Diagram VI. as continuous with the mammilla on each side (in the actual picture of section only one side is perfect).

Coming now to the actual photograph of the section (D), below the lumen of the valve mammilla, the mucous membrane, and submucous tissue, the muscular tissue of the ileum forming a shelf, is cut across obliquely (as explained in Diagram V.). Following the muscular coats to the left half of the valve mammilla in the photograph, it will be observed that the circular coat of the ileum (*c.m.i.*) is continuous with the internal circular muscular coat of the valve mammilla (*i.c.m.v.*). The longitudinal coat of the ileum (*l.m.i.*), seen cut transversely across in the region of the shelf below the lumen, is continuous

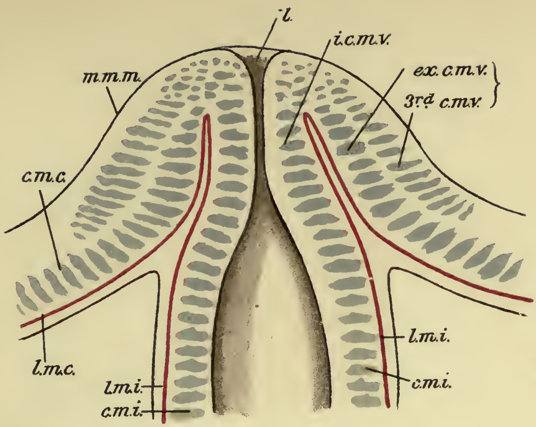

DIAGRAM IV.
Circular muscular tissue blue. Longitudinal muscular tissue red.

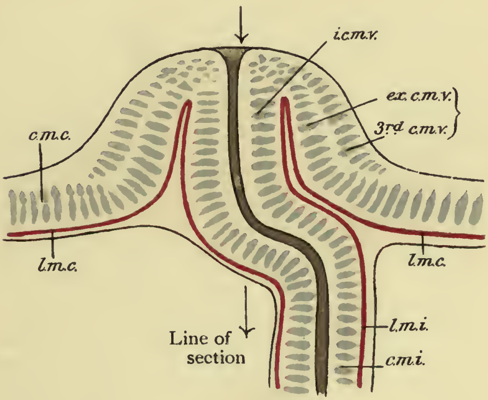

DIAGRAM V.

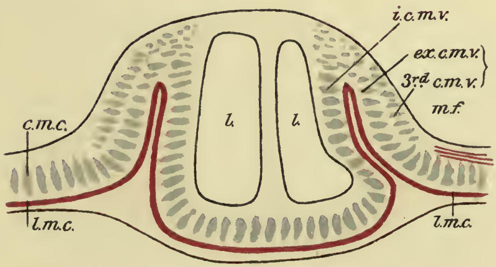

DIAGRAM VI.

with fibres longitudinally cut, running vertically in the valve mammilla between the internal circular muscular layer of the valve mammilla (*i.c.m.v.*) and the external circular muscular layer of the valve mammilla (*ex.c.m.v.*).

Looking now at the extreme left of the section, under the mucous membrane of mammilla (*m.m.m.*) and submucous tissue, the circular muscular coat of the large intestine is seen (*c.m.c.*) cut obliquely. Following this coat (*c.m.c.*) into the valve mammilla, it will be seen to be continuous with the external circular muscular layer (*ex.c.m.v.*) of the valve mammilla. To the left of the external circular coat—that is, outside it again—will be noticed circular muscular fibres forming a third circular coat, which is probably a reduplication of the external circular muscular layer of the valve mammilla (*ex.c.m.v.*). This will be referred to as the third circular muscular layer of the valve mammilla (*3rd c.m.v.*), although probably not a separate coat.

This third circular muscular layer is of great importance, for it shows that not only are the circular fibres duplicated in the valve mammilla by the entry of the coats of the large and small intestines, but that there is a further circular coat formed probably by the reduplication of the external circular muscular coat of the valve mammilla. The action of this third circular muscular layer will be to strengthen the sphincter action of the other two circular muscular layers (*i.c.m.v.* and *ex.c.m.v.*). It is difficult to determine the comparative thickness of the muscular coats of the ileum and of the large bowel, and the corresponding coats in the valve mammilla in a section; but from the section it is reasonable to suppose that the coats in the mammilla are at least as thick as the corresponding coats in the intestines, with which they are continuous. So that it follows that the duplication of the circular muscular fibres in the valve mammilla will

render it stronger in sphincter action than the circular muscular coats of the large or the small bowel. When to this is added the action of the third circular muscular layer of the valve mammilla (*3rd c.m.v.*), it will be seen that there is constituted a sphincter apparatus of considerable strength.

Turning again to the muscular coat of the large intestine at the extreme left of the picture, under the circular muscular coat (*c.m.c.*) of the large bowel is seen the longitudinal muscular coat of the large bowel (*l.m.c.*).

Following the longitudinal coat (*l.m.c.*) to the right, it will be seen to enter the valve mammilla beneath the external muscular coat of the mammilla (*ex.c.m.v.*). Here it is seen to be continuous with fibres which converge towards the longitudinal coat coming from the ileum (*l.m.i.*). The angle between these two sheets of muscular fibres is taken up with longitudinal bundles. In the substance of the mammilla the longitudinal fibres run parallel with one another to form one coat.

The right half of the valve mammilla is cut obliquely, as may be seen by the shape of the lumen in this position (*l.*), so that it will not be considered, except in regard to the muscular bands in the position of the frenula (*m.f.*) seen in close apposition to the circular layers of the sphincter. However, in this photograph (D) of Specimen 11 the left half of the valve mammilla does not show the circular and longitudinal coats merging into one common circular layer of fine bundles, as other sections not shown did (represented in Diagrams IV., V., and VI.). Probably because the apex of the mammilla is cut obliquely.

11. Presents the ileo-cæcal orifice as an almost perfect hemisphere. The opening is irregularly stellate, and presents several lobular corrugations. The orifice is closed further in by the continuation of the corrugations.

Opening across the furrow, 7 millimetres, but completely closed within the mammilla.

Frenula, slight, but accentuated in photograph.

Upper lip, 3 millimetres above colon.

Lower lip, 1 centimetre above cæcum.

Vertical diameter of mammilla, 1·8 centimetres.

Transverse diameter of mammilla, 1·9 centimetres.

Post-mortem, twenty-four hours after death; hydrocyanic acid poisoning.

Average temperature of room at time of death, 50° F.

Sex, male.

12. Shows the eminence of the ileo-cæcal valve as irregularly oval.

Opening, transverse diameter, 1·3 centimetres; vertical, 8 millimetres.

Frenula, indistinct.

Upper lip, 4 millimetres above colon.

Lower lip, 3 millimetres above cæcum.

Vertical diameter of mammilla, 1·8 centimetres.

Transverse diameter of mammilla, 2·2 centimetres.

Post-mortem, twenty-four hours after death.

Average temperature of room at time of death, 60° F.

Sex, male.

13. The cæcum is pulled down to expose the valve, which is seen as an irregularly hemispherical eminence.

Opening, irregularly triradiate; greatest transverse diameter, 4 millimetres.

Frenula, not marked, but accentuated by position of the cæcum.

Transverse diameter of prominence, 1·4 centimetres.

Vertical diameter of prominence, 1·5 centimetres.

Post-mortem, twelve hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

14. The valve mammilla is large and prominent. It is roughly hemispherical, with an irregularly oval opening. showing lobulation of the circumference of opening.

Transverse diameter of *opening*, 1·5 centimetres.
Transverse diameter of prominence, 3 centimetres.
Vertical diameter of prominence, 1·5 centimetres.
Frenula, present.
Lower portion of the valve flush with cæcum anteriorly, 0·5 centimetre posteriorly.
Upper portion, 1 centimetre above colon.
Post-mortem, thirteen hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

15. Form of the valve eminence is seen as an irregular hemisphere. The opening is relaxed, and of the form of an irregular hemisphere. The margin of the circumference of the opening shows distinct lobulation of the mucous membrane.

Transverse diameter of *Opening*, 1·3 centimetres.
Frenula, present.
Transverse diameter of prominence, 2·4 centimetres.
Vertical diameter of prominence, 1 centimetre.
Upper part of circumference, 0·4 centimetre from cæcum.
Lower part of circumference, 0·5 centimetre from colon.
Post-mortem, twelve hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

16. Shows the valve mammilla continued into the posterior frenulum and less markedly into the anterior, forming a distinct shelf between. The opening of the valve is elongated (slightly enlarged in photograph).

Length of valve orifice, 1·4 centimetres.
Valve mammilla, vertical diameter, 0·6 centimetre.
Valve mammilla, transverse diameter, 2·7 centimetres.
Upper surface flush with colon.
Lower surface, 0·6 centimetre above cæcum.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

17. Shows a large valve mammilla partially relaxed. The orifice is irregularly oval, and shows lobulated edges (slightly enlarged).

Opening, 1·2 centimetres.
Valve mammilla, vertical diameter, 1·8 centimetres.
Valve mammilla, transverse diameter, 2·8 centimetres.
Upper circumference above colon, 0·8 centimetre.
Lower circumference above cæcum, 0·4 centimetre.
Frenula, present.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

18. Shows the valve mammilla relaxed.

Opening, elongated.
Transverse diameter, 2·4 centimetres.
Valve mammilla, transverse diameter, 3·2 centimetres.
Valve mammilla, vertical diameter, 1·6 centimetres.
Upper circumference above colon, 0·8 centimetre.
Lower circumference above cæcum, 0·5 centimetre.
Post-mortem, twenty-four hours after death.

Average temperature of room at time of death, 60° F.

Sex, male.

19. The valve mammilla is seen prominently and partly relaxed. The orifice of the valve shows marked lobulation.

Both *Frenula* present.

Valve mammilla *Opening*, 1·9 centimetres.

Vertical diameter of mammilla, 1·6 centimetres.

Transverse diameter of mammilla, 2·3 centimetres.

Upper circumference flush with colon.

Lower circumference above cæcum, 0·5 centimetre.

Post-mortem, twelve hours after death.

Average temperature of room at time of death, 60° F.

Sex, female.

20. Presents the almost circular valve mammilla, with the orifice slightly relaxed, and showing lobulation of margin. The circumference of the valve is, roughly, 0·4 centimetre above the bowel, higher in the centre. The specimen is of interest, considering that it was obtained three hours after death. Relaxation of the orifice, however, is marked, due to the temperature and possibly to the cause of death (accidental electrocution).

Opening, 0·7 centimetre.

Frenula, absent.

Valve mammilla, transverse diameter, 2·4 centimetres.

Valve mammilla, vertical diameter, 2 centimetres.

Upper circumference above colon, 0·3 centimetre.

Lower circumference above cæcum, 0·4 centimetre.

Post-mortem, three hours after death.

Average temperature of room at time of death, 60° F.

Sex, male.

21. Shows prominent valve mammilla, with marked frenula at either side.

Opening, transverse, 1·5 centimetres.

Valve mammilla, transverse diameter, 2·4 centimetres.

Valve mammilla, vertical diameter, 0·9 centimetre.

Circumference of valve mammilla above colon, 0·4 centimetre.

Circumference of valve mammilla above cæcum, 0·5 centimetre.

Post-mortem, twelve hours after death.

Average temperature of room at time of death, 60° F.

Sex, male.

22. Shows the valve mammilla less prominent than usual, with the orifice relaxed.

Transverse diameter of *Opening*, 2·1 centimetres.

Valve mammilla, transverse diameter, 2·9 centimetres.

Valve mammilla, vertical diameter, 1·2 centimetres.

Upper circumference flush with colon.

Lower circumference 1 centimetre above cæcum.

Post-mortem, twenty-four hours after death.

Average temperature of room at time of death, 60° F.

Sex, male.

23. Presents a relaxed valve mammilla.

Opening, transverse, 1·7 centimetres.

Valve mammilla, transverse diameter, 2·6 centimetres.

Valve mammilla, vertical diameter, 0·6 centimetre.

Circumference of valve mammilla above colon, 0·2 centimetre.

Circumference of valve mammilla above cæcum, 0·4 centimetre.

Frenula, marked.

Post-mortem, twenty-three hours after death.

Average temperature of room at time of death, 60° F.

Sex, male.

24. Presents almost circular valve mammilla, with irregularly circular opening.

Frenula, present.

Opening, transverse diameter, 1·3 centimetres.

Opening, vertical diameter, 0·7 centimetre.

Valve mammilla, transverse diameter, 2·3 centimetres.

Valve mammilla, vertical diameter, 1·7 centimetres.

Circumference of valve mammilla above colon, 0·2 centimetre.

Circumference of valve mammilla above cæcum, 0·7 centimetre.

Post-mortem, ten hours (accidental electrocution) after death.

Average temperature of room at time of death, 60° F.

Sex, male.

25. Presents irregularly circular valve mammilla. The orifice is nearly closed, and shows lobular corrugations at the edge.

Frenula, absent.

Valve mammilla, vertical diameter, 1·4 centimetres.

Valve mammilla, transverse diameter, 1·7 centimetres.

Post-mortem, twelve hours after death.

Average temperature of room at time of death, 50° F.

Sex, male.

26. Mammillary eminence oval in form.

Transverse diameter, 2·4 centimetres.
Vertical diameter, 1·3 centimetres.
Opening, transverse, 1·4 centimetres.
Height of mammilla above cæcum, 0·7 centimetre.
Height of mammilla above colon, 1·2 centimetres.
Frenula, present.
Specimen obtained at post-mortem forty-eight hours after death.
Average temperature of room at time of death, 60° F. (about).
Sex, male.

27. Valve mammilla oval in form; lips show lobulation.

Mammillary eminence, transverse diameter, 2·7 centimetres.
Mammillary eminence, vertical diameter, 1·4 centimetres.
Transverse diameter of opening, 1·4 centimetres.
Height of mammilla above cæcum, 0·9 centimetre.
Height of mammilla above colon, 0·7 centimetre.
Frenula, present.
Specimen obtained about twenty-four hours post mortem.
Average temperature of room at time of death, 60° F.
Sex, male.

28. The mammillary eminence is continued into frenula.

Transverse diameter of mammillary eminence, 2·6 centimetres.
Vertical diameter of mammillary eminence, 1·2 centimetres.

Transverse diameter of opening, 1·6 centimetres.
Frenula, marked.
Height of mammilla above cæcum, 0·2 centimetre.
Height of mammilla above colon, 0·9 centimetre.
Post-mortem, twenty-four hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

29. The mammillary eminence is presented in a form flattened from above downwards.

The transverse diameter of mammillary eminence, 3·3 centimetres.
The vertical diameter of mammillary eminence, 1·7 centimetres.
Transverse diameter of opening, 2 centimetres.
Height of mammilla above cæcum, 1·1 centimetres.
Height of mammilla above colon, 0·0 centimetre (on the same level).
Frenula, present.
Post-mortem, eighteen hours after death.
Average temperature of room at time of death, 60° F.
Sex, male.

30. Presents a large mammillary eminence.

Transverse diameter of mammillary eminence, 4·5 centimetres.
Vertical diameter of mammillary eminence, 2·8 centimetres.
Transverse diameter of opening, 2·3 centimetres.
Height of mammilla above cæcum, 0·7 centimetre.
Height of mammilla above colon, 0·7 centimetre.
Frenula, present.
Specimen obtained twenty-four hours post mortem.
Average temperature of room at time of death, 60° F.
Sex, male.

31. Chinaman.

Transverse diameter of mammillary eminence, 2·5 centimetres.

Vertical diameter of mammillary eminence, 2·6 centimetres.

Transverse diameter of opening, 0·6 centimetre.

Height of valve mammilla above cæcum, 0·6 centimetre.

Height of valve mammilla above colon, 0·6 centimetre.

Frenula, present.

Specimen obtained twenty-nine hours post mortem.

Average temperature of room at time of death, 60° F.

Sex, male.

32. Presents a valve mammilla of oval form.

Transverse diameter of valve mammilla, 2·6 centimetres.

Vertical diameter of valve mammilla, 1·7 centimetres.

Transverse diameter of opening, 1·4 centimetres.

Frenula, marked.

Height of valve mammilla above cæcum, 0·0 centimetre (on the same level).

Height of valve mammilla above colon, 1·1 centimetres.

Specimen obtained twenty-four hours post mortem.

Average temperature of room at time of death, 60° F.

Sex, female.

SUMMARY OF SERIES OF SPECIMENS.

The preceding series of specimens may be divided, roughly, into three classes:

1. Specimens showing the valve mammilla as a more or less perfect hemisphere. These present no frenula.
2. Specimens, oval in form, presenting frenula.
3. Specimens presenting the valve mammilla as a slit presenting frenula.

1. Specimens showing the valve mammilla as a more or less perfect hemisphere. These present no frenula. Amongst these are included 1, 2, 11, 13, 20, 25.

If the data concerning these be studied, it will be seen that these specimens are those obtained shortly after death, usually in cold weather. The form of the valve mammilla is a more or less perfect hemisphere, the diameter of the hemisphere being about 1·8 centimetres. It will be seen that the transverse and vertical diameters of the valve mammilla in some are almost equal, whilst in others the transverse diameter is somewhat greater than the vertical, this increase in the transverse diameter causing the form of these to more nearly approach the second division than the others of the first series. Amongst the most perfect of the hemispherical forms is No. 11. This specimen was from a case of hydrocyanic acid poisoning, twelve hours after death in winter. In the photograph, what appear to be frenula are in reality folds of mucous membrane accentuated in exposing the valve mammilla for the photograph. In appearance the valve mammilla in the first series of specimens gives one the impression of a firm hemispherical button. Looking at the orifice, it will be observed that in the hemispherical forms the orifice is in the centre of the mammilla. In form the orifice is roughly stellate,

some of the orifices showing as many as five rays to the star. The tendency is shown in most of the specimens for the transverse rays of the star to be longer and most pronounced. Probably this fact is due to the tissue other than muscular, in the position in which the so-called frenula appear after death, exerting post-mortem traction upon the lateral circumferences of the valve mammilla, whereby the valve is pulled out first into the oval form and then into the form of a slit. This is borne out by the observation that in the complete relaxation of the muscular tissue of the valve mammilla and of the large bowel generally, as seen in the dissecting-room, the valve is seen as a slit with frenula, instead of the more or less circular form shown in pictures of recent specimens in modern textbooks preserved with formalin. Also it is borne out by the description of the valve mammilla during life, when the patient was under deep chloroform anæsthesia (*supra*, p. 29). Under deep chloroform anæsthesia the valve mammilla was found to have changed from a prominent hemispherical mass, with firm rubber-ball-like feeling, when taken between the fingers, into a slit about 2½ centimetres long, running upwards and inwards at an angle of about 45 degrees to the transverse plane of the body. Instead of the firm round mass the edges of the slit were then almost flush with the colon and cæcum, and the relaxed muscular tissue, which, while in contraction, had formed the prominent hemispherical mass of the valve mammilla, now felt merely as a thickening along the edges of the slit at the termination of the ileum. If, as seems reasonable to suppose, the muscular tissue in the colon and cæcal wall becomes relaxed *pari passu* with that in the valve mammilla, we would have expected the valve mammilla to have become a circular relaxed ring if the muscle in the walls of the bowel were the only force exerted on the circumference of the valve mammilla.

However, the slit-like form under chloroform goes to show that another force is present, as the muscular tissue is completely relaxed. Merkel, however, shows a vertical slit.

As will be shown later, in the third series of specimens, in complete relaxation post mortem, there is frequently a marked partition at the position of the frenula between the colon and cæcum.

Reverting to the stellate appearance of the orifice between the corrugations of the star will be noticed lobular thickening of the edges of the valve, due to the tube of mucous membrane in the lumen of the valve becoming puckered during contraction of the circular muscular fibres contained in the valve sphincter. There is practically no appearance of frenula, showing that the muscular tissue has been hardened before much relaxation has taken place.

2. Specimens, oval in form, presenting frenula in nearly all cases, represented by 3, 8, 9, 10, 12, 14, 17, 19, 21, 23, 24, 26, 29, 30, 31, 32, obtained from twenty-four to forty-eight hours in cold weather, or earlier in hot weather.

This group of specimens differs from the last in the form of the valve mammilla, which is oval instead of rounded. In considering the valve mammilla we notice it still projects from the wall of the large bowel in little less marked degree than the former series. About the orifice are noticed the depressions between lobular thickenings. The orifice of the valve is relaxed into an oval form in most cases, not into a slit. The mucous membrane at each end of the oval mammilla is noticed to be prominent, giving rise, with the subsequent tissue, to thickened bands or frenula.

3. Specimens presenting the valve mammilla as a slit, presenting also frenula. Represented by Specimens 4, 5, 6, 7, 15, 16, 18, 22, 27, 28.

These specimens were obtained usually from twenty-four to forty-eight hours after death, often in hot weather.

This series present the valve mammilla in a state of more or less complete relaxation. The valve mammilla has lost almost entirely its hemispherical form, though still retaining somewhat of the oval form. In appearance the valve mammilla, nearly flush with the colon and cæcum, now resembles two lips separated by a slit-like orifice.

Turning now to the orifice, this is nearly straight, and has lost the appearance of lobulation at its edge.

From the mucous membrane, at the two extremities of the slit, the frenula of the valve are seen to be present, in some cases actually forming, with the relaxed valve mammilla, a partition or shelf between the colon and cæcum. This shelf is probably due to post-mortem relaxation and loss of the elastic property of the muscular fibres, whereby these fibres lose their usual form as seen in life and shortly after death.

Final Summary.

At the termination of the first part of this thesis dealing with the literature of the valve, there were several points to be decided by the second portion, which deals with original observations—viz.:

1. On the ileo-cæcal valve mammilla of a living subject.

2. The observation of a rounded mass of muscular tissue, about 2 centimetres in diameter, in several cases of operation for removal of the appendix at the termination of the ileum, where the patients were under light ether anæsthesia.

3. A series of thirty-two specimens removed soon after death, and preserved in 10 per cent. formalin.

The points to be decided were—

1. What is the normal appearance of the valve ?
2. Is the valve normally competent ?
3. What is the function of the valve ?
4. What is the value of the muscular fibres ?

1. In answer to Question 1, the normal appearance of the valve is in the form of hemispherical mammillary eminence, about 1·8 centimetres in diameter, scarlet in appearance, smooth, and glistening. The summit is truncated, and pierced by an orifice of a stellate appearance, with lobulated elevations between the rays of the star. This elevation is about 0·5 to 1 centimetre high. Surrounding the valve mammilla, of scarlet appearance, is the mucous membrane of the colon and cæcum, which is of a pink colour. No frenula are to be seen in life.

2. Is the valve normally competent ? The valve is competent during life.

3. What is the function of the valve ? The function of the valve is that of a sphincter similar to the pylorus and the internal anal sphincter, and is twofold: (*a*) To regulate the flow of semifluid fæces through the valve; (*b*) to prevent regurgitation.

4. What is the value of the muscular fibres in the valve ? As has been shown in the microscopical sections, the muscular fibres in the valve mammilla are important, and are arranged in several layers, the circular fibres forming collectively a powerful sphincter muscle. Not only are the circular and longitudinal muscular coats from the large and small intestine continued into the valve mammilla, to become fused at its summit into one common circular layer, but also there is a muscular layer peculiar to the valve mammilla, probably a reduplication of the external circular layer (*ex.c.m.v.*), termed, for the sake of emphasis, the third "circular muscular layer of the valve mammilla" (3*rd c.m.v.*). At the summit of the

valve these three circular layers fuse into one common circular layer. Further, in the position in which the frenula appear after death, there are situated muscular fibres which take origin in the mammilla at right angles to, and perhaps interlacing with, the fasciculi of the third circular muscular coat of the valve mammilla.

The longitudinal muscular fibres, by their contraction, open the valvula coli, assisted probably by the muscular contraction of the fibres situated in the position the frenula occupy after death.

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DESCRIPTION OF PLATES

FRONTISPIECE. — COLOURED REPRESENTATION OF SECTION FIGURED ON PLATE D.

PLATE

A. FIGS. 1-32. — PHOTOGRAPHIC PLATES CORRESPONDING TO DESCRIPTIONS OF THIRTY-TWO HUMAN SPECIMENS (SUPRA, pp. 36-55).

B. PHOTOGRAPHIC PLATE REPRESENTING MICROSCOPICAL SECTION ACROSS BASE OF VALVE MAMMILLA OF SPECIMEN No. 2 (PLATE A, FIG. 2).

C. PHOTOGRAPHIC PLATE REPRESENTING MICROSCOPICAL VERTICAL SECTION OF VALVE MAMMILLA OF SPECIMEN No. 2 (PLATE A, FIG. 2).

D. PHOTOGRAPHIC PLATE REPRESENTING MICROSCOPICAL VERTICAL SECTION OF SPECIMEN No. 11 (PLATE A, FIG. 11).

E. PHOTOGRAPHIC PLATES OF ILEO-CÆCAL VALVE IN DOG, NATURAL SIZE (*a*) AND ENLARGED (*b*).

LETTERING COMMON TO ALL FIGURES.

l. =Lumen.
m.m.l. =Mucous membrane of lumen.
lym.t. =Lymphoid tissue.
sub.m.l. =Submucous tissue of lumen.
i.c.m.v. =Internal circular muscle layer of valve mammilla.
l.m.v. =Longitudinal muscular layer of valve mammilla.
ex.c.m.v. =External circular muscle layer of valve mammilla.
m.f. =Muscular fibres in position of frenulum valvulæ coli.
sub.m.m. =Submucous tissue of mammilla.
m.m.m. =Mucous membrane of mammilla.
c.m.i. =Circular muscular coat of the ileum.
l.m.i. =Longitudinal muscular coat of the ileum.
c.m.c. =Circular muscular coat of large bowel.
l.m.c. =Longitudinal muscular coat of large bowel.
3rd c.m.v. =The third circular muscular layer of the valve mammilla, treated as a separate layer, though probably a reduplication of the external circular layer of valve mammilla (*ex.c.m.v.*).

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PLATE A (FIGS. 1 TO 32).—SPECIMENS HARDENED IN FORMALIN 10%.

FIG. 1.—Male. Dead, 6 hours. Average temperature of room at time of death, 50° F.

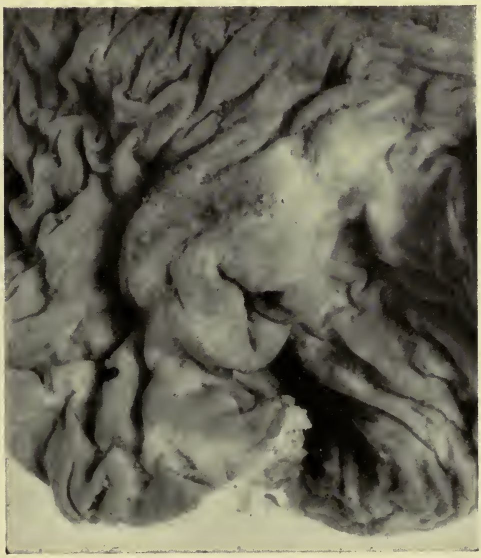

FIG. 2.—Male. Dead, 6 hours. Average temperature of room at time of death, 50° F.

Fig. 5.—Male. Dead, 36 hours. Average temperature of room at time of death, 50° F.

Fig. 6.—Male. Dead, 24 hours. Average temperature of room at time of death, 50° F.

Fig. 7.—Male. Dead, 24 hours. Average temperature of room at time of death, 55° F.

Fig. 8.—Male. Dead, 24 hours. Average temperature of room at time of death, 50° F.

Fig. 9.—Male. Dead, 24 hours. Average temperature of room at time of death, 55° F.

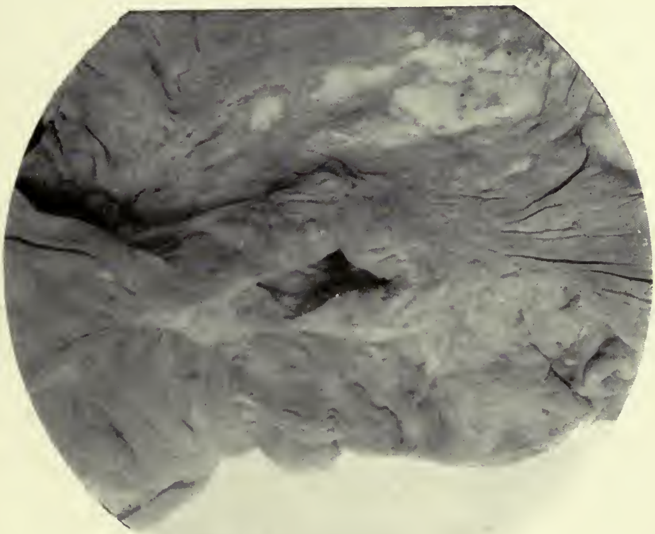

Fig. 10.—Male. Dead, 26 hours. Average temperature of room at time of death, 60° F.

Fig. 11.—Male. Dead, 24 hours. Average temperature of room at time of death, 50° F.

Fig. 12.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F.

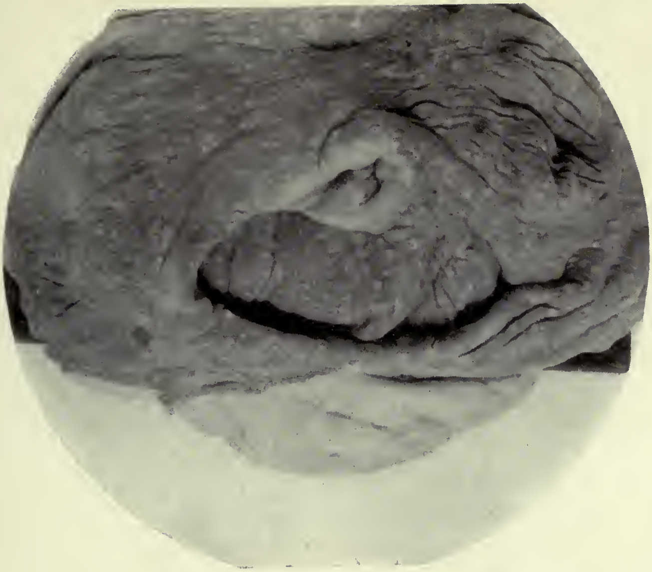

Fig. 13.—Male. Dead, 12 hours. Average temperature of room at time of death, 06° F.

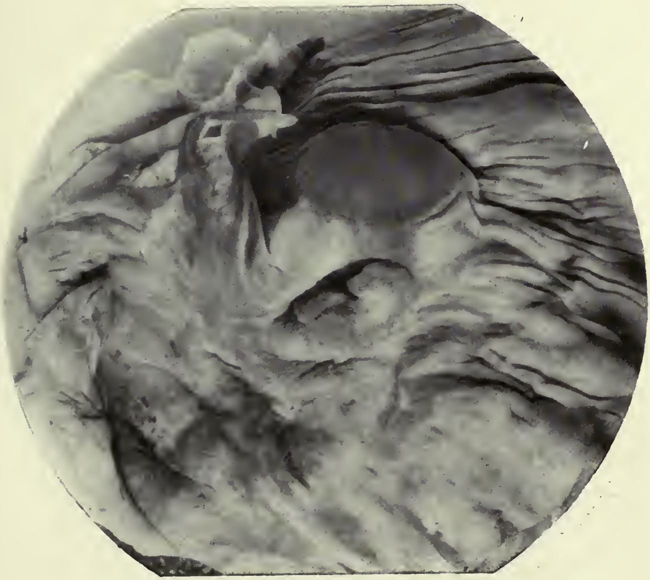

Fig. 14.—Male. Dead, 13 hours. Average temperature of room at time of death, 60° F.

Fig. 15.—Male. Dead, 12 hours. Average temperature of room at time of death, 60° F.

Fig. 16.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F.

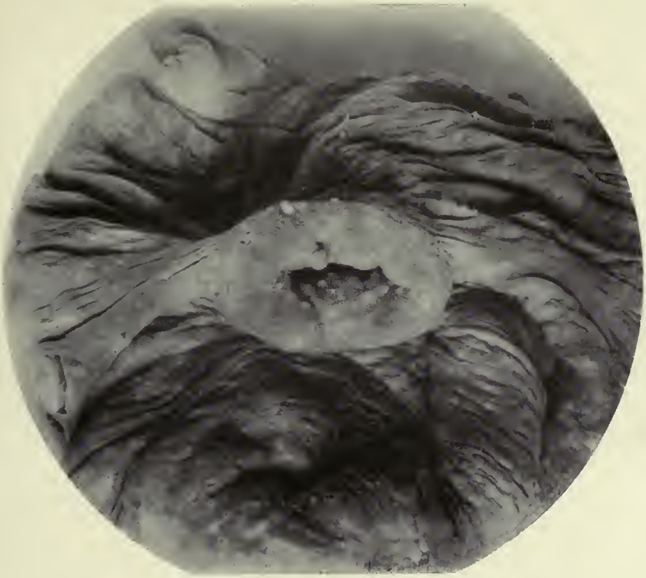

Fig. 17.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F

Fig. 18.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F.

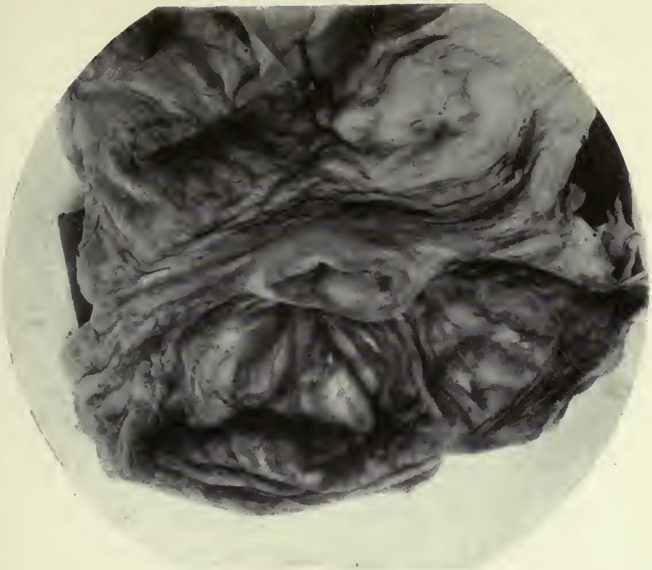

Fig. 19.—Female. Dead, 12 hours. Average temperature of room at time of death, 60° F.

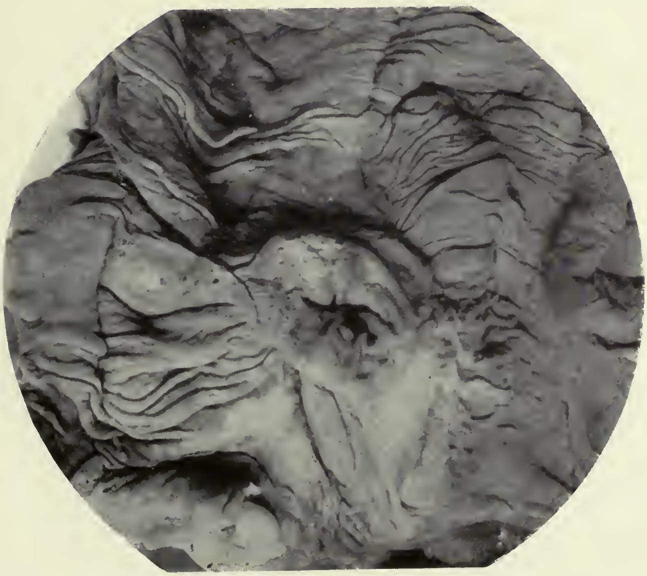

Fig. 20.—Male. Dead, 3 hours. Average temperature of room at time of death, 60° F.

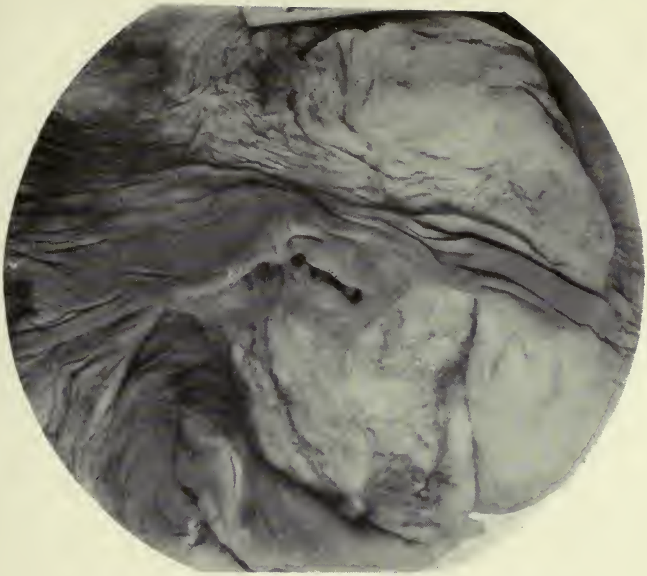

FIG. 21.—Male. Dead, 12 hours. Average temperature of room at time of death, 60° F.

FIG. 22.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F.

FIG. 23.—Male. Dead, 23 hours. Average temperature of room at time of death, 60° F.

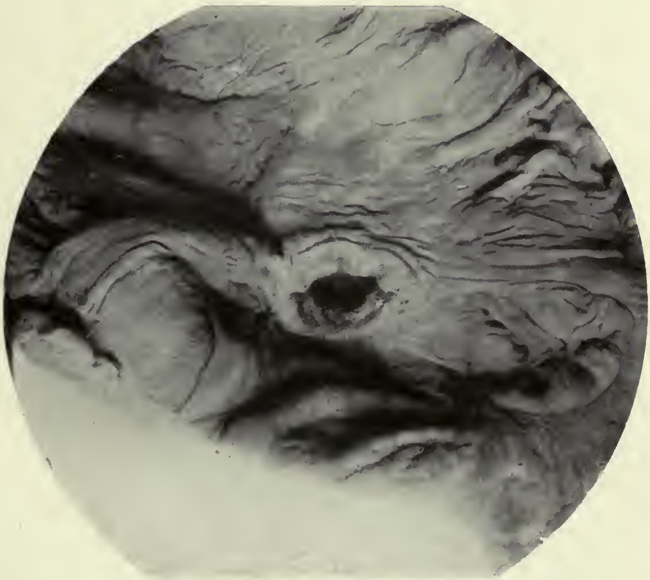

FIG. 24.—Male. Dead, 10 hours. Average temperature of room at time of death, 60° F.

Fig. 25.—Male. Dead, 12 hours. Average temperature of room at time of death about 50° F.

Fig. 26.—Male. Dead, 48 hours. Average temperature of room at time of death about 60° F.

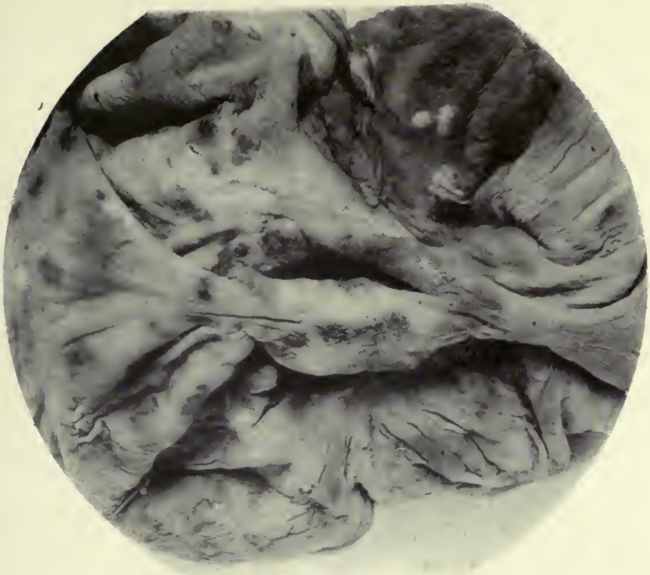

Fig. 27.—Male. Dead, about 24 hours. Average temperature of room at time of death, 60° F.

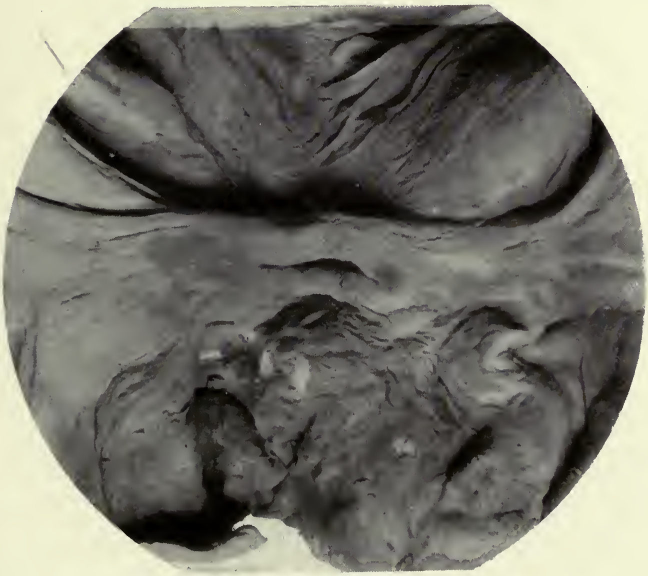

Fig. 28.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F.

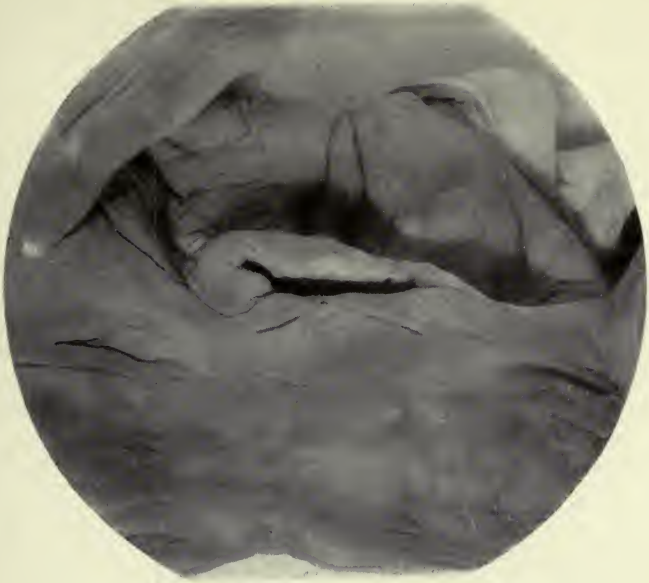

Fig. 29.—Male. Dead, 18 hours. Average temperature of room at time of death, 60° F.

Fig. 30.—Male. Dead, 24 hours. Average temperature of room at time of death, 60° F.

FIG. 31.—Male. Dead, 29 hours. Average temperature of room at time of death, 60° F.

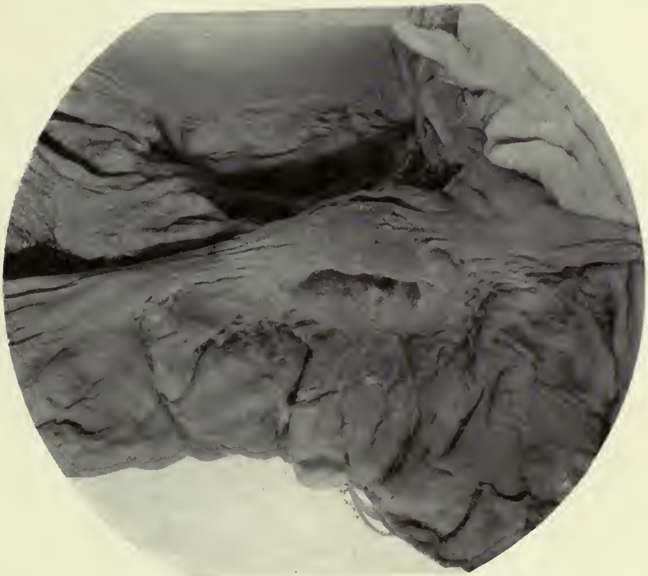

FIG. 32.—Female. Dead, 24 hours. Average temperature of room at time of death, 60° F.

PLATE B.
PLATE B.

PLATE B.

PLATE B.

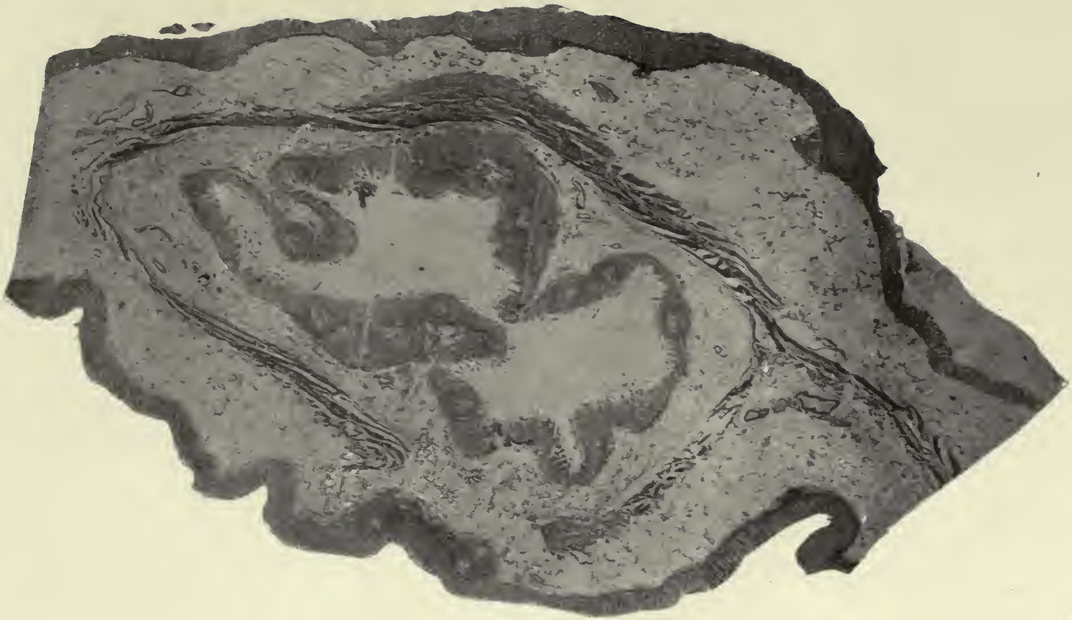

PLATE C.

1.—Internal circular muscle layer of valve mammilla.

2.—External circular muscle layer of valve mammilla.

3.—The third circular muscular layer of the valve mammilla.

l.m.v.—Longitudinal muscular layer of valve mammilla.

PLATE C.

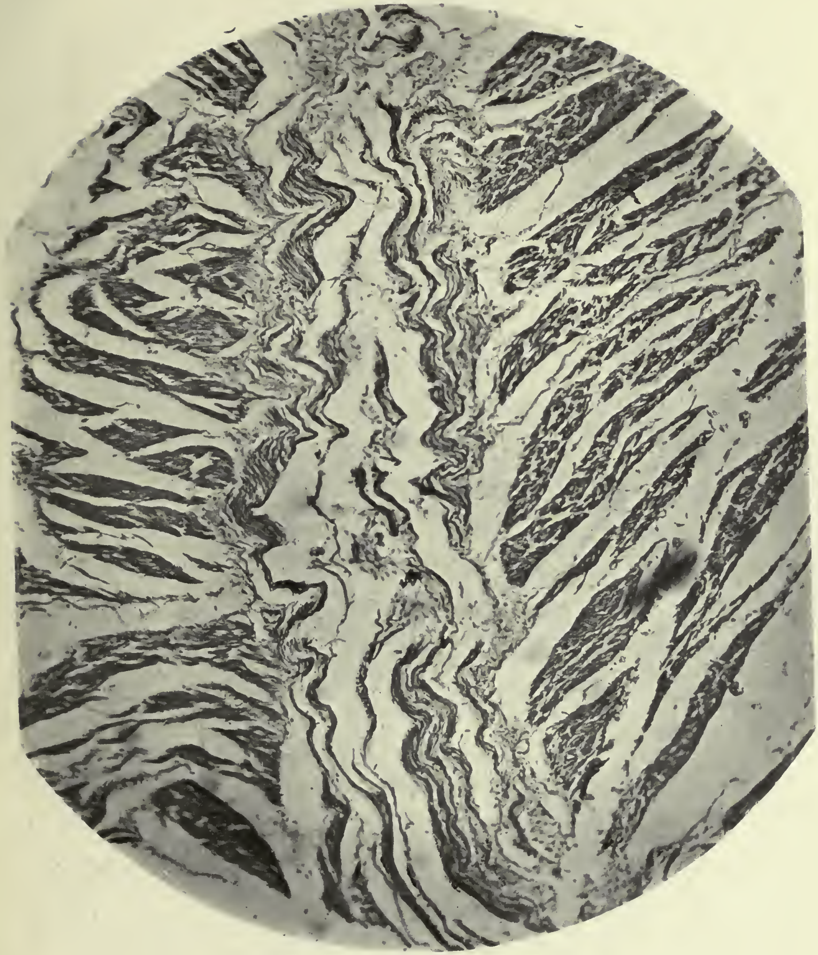

PLATE D.


m.m.m.
sub. m. m.
m.f.
m. m. l.
sub. m. l.
l.
lym. t.
c.m.i.
l.m.i.
3rd.c.m.v.
c.m.c.
l.m.c.
ex.c.m.v.
l.m.v.
i.c.m.v.

PLATE D.

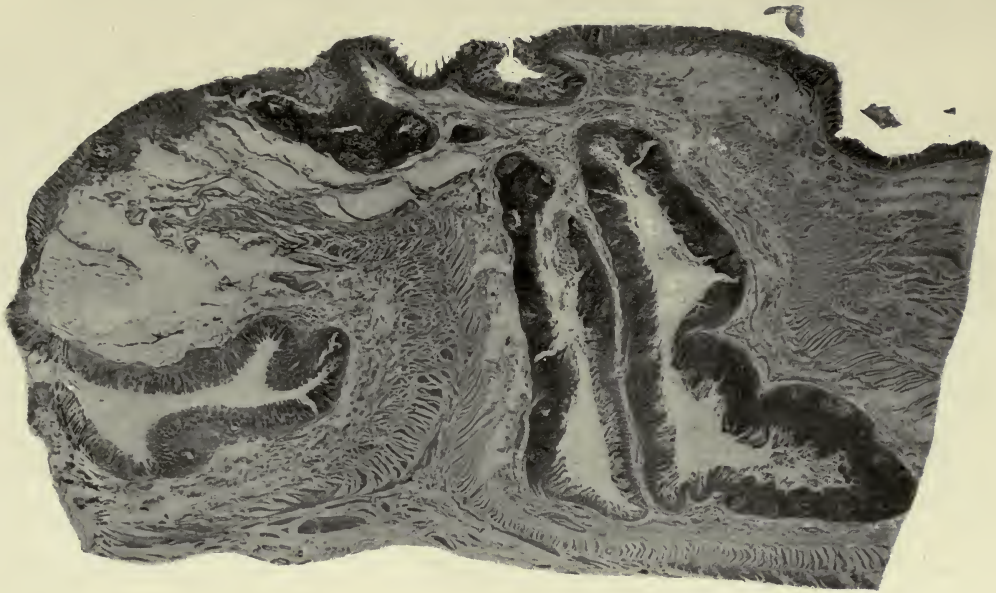

PLATE E.—ILEO-CÆCAL VALVE OF DOG.

(*a*) Photograph of ileo-cæcal valve mammilla in a dog 16 kilos in weight.

(*b*) Enlargement of same.

sphincter - not a valve -

exertement
pain
Surges
bryng in colon

Summary -

Diff in color - ileum redder